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Seed Testing

Its Uses and Methods

ISSUED BY THE
NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION
RALEIGH, N. C.

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N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

THE NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

INCLUDING

THE FERTILIZER CONTROL STATION

AND THE STATE WEATHER SERVICE,

UNDER THE CONTROL OF THE

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RALEIGH, N. C.

PREFACE.

The matter contained in this Bulletin is the result of several years of labor, both in carefully-conducted tests and in data collected in this country and abroad.

The question of good seed for planting is known to be a most important one. While there are many well-established seed houses who would not knowingly deceive in placing their goods on the market, yet it is certain that there are others who are not so scrupulous, who sell bad and adulterated seed either through ignorance or design. Evidence upon this point is too strong to admit of a doubt. Even the conscientious seedsmen may be liable to buy adulterated seed, and sell them to others without knowing their true character.

Seed testing is of value both to seedsmen and to purchasers. To seedsmen on the one hand, in enabling them to understand the real nature of the material they buy before selling to others; to buyers, on the other, to enable them to know if the seed they propose planting are vital seed, and free from every objectionable weed adulteration.

An official seed control may be open to many objections, and might not be advisable at this time. A voluntary seed control does not possess the objectionable features of a legal enactment, and it may prove to be a satisfactory solution to the present difficulty. Such a control is managed without the enaction of law. It is inaugurated by means of the voluntary co-operation of both sellers and buyers, and is governed by the laws of trade and mutual benefit. The fundamental principle upon which such a control is based is the progressive spirit of seedsmen who agree to sell living seed of certain stated percentages of vitality, and free from adulterations. If after testing, it is found that the seed does not reach this quality or contains any adulterations, the seedsmen agree to take back the seed, paying transportation charges each way, or else refund a proportional part of the cost of the seed. No claim for damages to extend beyond thirty days, or after the seed is sown. The guarantee is only a guarantee that the seed is what is claimed for it, and does not extend to the quality of the crop. Evidently there are too many conditions affecting the growth of the seed in the soil for any guarantee to be given as to the yield. Bad preparation of the land, too deep or too thin covering of the seed, bad weather conditions, are some of the most common conditions injuriously affecting growth of crops, and for these the seedsman is certainly not responsible.

Competition is the soul of trade, but fair competition is possible only when competing goods are sold upon their real merits, as must be the case when seed are sold under a definite guarantee based upon a standard method of scientific analysis. If some enterprising dealers, knowing thoroughly the quality of seed they sell, voluntarily state that the goods are what they claim and subject to the above guarantee, then it will not be strange if they should commence to handle the bulk of the trade. Purchasers undoubtedly will buy where they can get the best seed for the money.

The present bulletin endeavors to show to the purchaser the prime necessity for buying only pure and unadulterated seed, and at the same time describes the value and need of seed testing. The methods and apparatus used in testing seeds are elaborated, and a seed standard and a method of voluntary seed control is suggested.

The whole matter may now be left with an enlightened and discriminating public.

H. B. BATTLE,
Director.

TABLE OF CONTENTS.

	PAGE.
Preface	347
Seed testing; its uses and methods	349
The uses of seed testing	349
Seed testing in the United States	355
The seed control system in Europe	357
The method of seed control	360a
The physiology of the seed	361
The structure of the seed	361
The germination of seeds	362
The proximate composition of the endosperm	364
The mineral constituents of the seed	365
The effect of temperature on the germination process	365
The action of light and electricity upon the germination of seeds	368
The action of chemicals upon the germination of seeds	369
The specific gravity of seeds	371
The volume-weight of seeds	372
The life of the plant embryo	374
The harvest stage	374
The germinating stage; seed viability	374
The inert stage	378
Practical seed testing	382
Viability, purity and germination of seeds	382
Seed, their impurities and adulterations	386
The grass family	386
The clover family	391
Limit of possible error in seed testing	394
Methods and apparatus used in seed testing	397
Germinating apparatus	397
The Nobbe germinating pan	398
The Zurich pan	398
The Vienna pan	399
The Kiel germinating apparatus	400
The Geneva (N. Y.) pan	400
The North Carolina pan	401
Other forms of germinating apparatus	402
Seed separators	402
Separation by sieves	402
The air separator or spreufuge	403
Simple and compound microscopes	404
Volume-weight apparatus	404
Sampling apparatus	404
Analytical balance	404
Miscellaneous apparatus	404
Record books and blanks	405
North Carolina Station records and blanks	405
Sampling blank	405
Seed record and register	406
Seed report blank	407
Zurich Station blanks	407
Seed mailing envelope	407
Preliminary report blank	408
Complete report blank	409
Private contract blank	411
Certificate of guarantee, and sample blank	412
Appendix	413
Index	414

SEED TESTING; ITS USES AND METHODS.

By Gerald McCarthy, Botanist.

I.

1.—THE USES OF SEED TESTING.

The seed sown upon well-prepared land is the beginning and fountain head of the crop which is to follow. Unless the seed is true to name, free from noxious impurities, and of at least average viability, the crop must fail to remunerate the sower. Although the seed is an all-important factor in the production of a crop, it is not the most expensive one. The cost of the seeding for most staple crops is inconsiderable compared with the cost of fertilizer, labor, and the yearly value of the land. Yet the failure of the seed means a more or less complete loss of the other items of expense. It is obvious then that "*for the seeding, the best is not good enough.*"

The use and value of scientific seed testing is to secure to the sower in sufficient time, a rational knowledge of the quality of the seeds he proposes to sow, and thereby protect himself against the loss and vexation of seeing his time, labor and money worse than wasted. The modern spirit of specialization and division of labor has placed the growth and purveyance of agricultural and horticultural seeds largely in the hands of specialists—seedsmen. That American seedsmen are as a whole as honest as those of any other country is without doubt true. It is equally true and proven by facts, some of which are quoted in this Bulletin, that there are in the trade persons who are neither honest nor competent to hold such responsible relationship to the agricultural prosperity of the country. The whole trade as at present conducted rests upon an unbusinesslike basis. The seedsmen are unwilling or unable to give a reasonable guarantee of the quality of their goods, and the purchaser is expected to pay current and full-weight coin of the country for goods of whose quality he has no assurance other than the word of a distant and unknown corporation or person whom he is never likely to meet. The establishment of a trustworthy standard of quality by which dealers and consumers may alike buy and sell seeds, and of a standard process of testing seeds to define their quality, is absolutely essential for further advance in the art of plant culture. Such standard and process will soon separate reputable and careful seed purveyors from those who have no reputation to lose, and seeds may then be bought and sold upon their intrinsic merits. Consumers will know what they purchase

and will be able to mix different species on a rational and quantitative basis. No honest man or corporation can be injured or embarrassed by such a course, and dishonest ones can be unmasked and exposed only by such exact and demonstrable methods as a seed testing station could employ. That the American seed market requires some such supervision in the interest of the consumer the subjoined communications and facts will serve to demonstrate.

One of the largest and most reputable seed firms in the United States has written to this Station as follows:

"You deserve very great credit for your efforts to bring about a reform in the supplying of grass seeds. The samples that are sometimes submitted to us by growers ars simply shocking. We would like to see some one placed in power in each State to pass upon the quality of samples sold to farmers. We feel sure that it would relieve *bona fide* seedsmen of a great responsibility, and would be the means of abolishing the enormous quantities of worthless seeds that are annually placed upon the market."

The following clipping from an agricultural paper, from the pen of a prominent horticulturist, may show the way some seed firms treat their patrons, and whether they need watching:

"From what I have learned through employees of some of our largest seedsmen, they are certainly not as upright as business men should be. A friend who went as stenographer to a large New England seed firm, told me, without being asked, that a bin was kept for miscellaneous varieties of pea seeds, and whenever an order came in for a variety not kept in stock, it was invariably filled from this bin. Another friend employed in one of the largest seed houses of the country, told me that it was the regular custom to run all onion seed left over from the previous year, through the fanning-mill with the fresh stock, and to send it out as "cleaned" seed. Still another friend employed in a very extensive seed house, stated, with regret, that his employers had no other interest in the handling of seeds than to get the most money possible from them without regard to moral or scientific questions."

The following extract is quoted by Dr. H. B. Battle, Director of the North Carolina Experiment Station, in the introduction to Bulletin 67 of this Station:

"A single extract from a paper read by Mr. J. E. Northup, of Minneapolis, before the Minnesota State Horticultural Society, will show what deception some seed houses adopt, and the consequent care which ought to be taken to prevent such practice from becoming widespread:

"'In walking through a large seed warehouse some time since, I detected the odor of burning brimstone, and my curiosity was aroused as to what part brimstone could play in the fitting of seed for market. Making some pretext for visiting that portion of the building from whence the fumes proceeded, I came to some cucumber seed, which was being bleached to remove the yellow tint with which age had mellowed it. The tags on the bags indicated that it had been in that building over twenty years, and how much longer no one knows.'

"In the preparation of seed, then, for the market, adulteration and deception must be guarded against, as much so as in other mercantile professions."

The following tables from Bulletin 15 of the Illinois Experiment Station show that poor seed is found in other than Southern markets:

TABLE SHOWING PERCENTAGES GROWING OF SEEDS OF KENTUCKY BLUE GRASS, RED TOP, AND TIMOTHY, TESTED IN GENEVA APPARATUS.

Number of Sample.	Kentucky Blue Grass.	Red Top.	Timothy.
1	7	16	94
2	3	*25	94
3	*1	*33	93
4	3	5	94
5	3	40	91
6	2	18	88
7	4	63	
8	2	50	96
9	6	32	58
10	0	4	59
11	0	5	75
12	2	32	42
13	0	8	57
14	0	21	81
15	0	18	78
16	1	33	69
17	1	11	52
Average	2	25	76+

*Two samples.

"It will be seen from this table that less than 2 per cent. of the blue grass, 25 per cent. of the red top, and a little more than 76 per cent. of the timothy sprouted. The maximum per cents. in each were 7, 63 and 96 respectively."

[NOTE.—Each of the above samples was purchased from a different and prominent seedsman.]

The same Station subsequently made the annexed tests of home-grown seed of Kentucky blue grass and comments as follows:

"The first tests made upon the vitality of Kentucky blue grass led to correspondence with all the seedsmen whose seeds were tested. It was stated by seedsmen that it is the practice to cut or strip Kentucky blue grass for seed while still quite green as more and cleaner seed could be obtained that way, but in curing it often heated and spoiled. It was decided to test this matter. The following table gives the results obtained:

TABLE SHOWING THE VITALITY OF HOME GROWN KENTUCKY BLUE GRASS SEED CURED IN DIFFERENT WAYS.

Condition of gathering and keeping the seed.	Number of seeds sprouted in a gram.			No. of seeds in a gram as sown	Per cent of seeds sprouting.
	a.	b.	Average.		
Gathered green and dried on floor in a dry room	2,994	2,737	2,866	3,954	72.5
Gathered green and dried in cellar	2,976	2,768	2,872	4,014	71.6
Gathered green and dried in grain sack	3,040	2,970	3,005	4,127	72.8
Gathered ripe and dried on floor in a dry room	3,069	2,851	2,960	3,695	80.1

"The per cent. of seeds sprouting in the three samples gathered green was practically alike, being a little more than 72 per cent.; while that of the ripe seed, on the basis of the number of seeds found in a gram, was somewhat higher, being 80 per cent. The seed gathered green and preserved in any of the three ways, two of which would be presumably unfavorable, had more than three times the vitality of 18 samples of blue grass seed received from 17 firms, and twice as great as any one of the samples so obtained.

"Three points are still to be determined: the vitality if gathered still greener; the vitality during a series of years, and the length of time the seed will retain its vitality. But the tests are sufficient to indicate that a better grade of Kentucky blue grass seed may fairly be expected of the seedsmen of this country."

The following tables, reprinted from Bulletin 67 of this Station, may serve to show the quality of seeds that purchasers are liable to obtain in markets where no supervision of quality is practiced or thought of.

GARDEN SEEDS—BOUGHT IN RALEIGH, N. C.

Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality, per cent.	Valuation, per cent.	Vitality of good seed of species named should be
Cabbage, L. L. Drumhead	4	10	100	45.5	45.5	89
Cabbage, Brunswick Drumhead	3	7	100	9.	9.	89
Cabbage, L. L. Bergen	7	8	100	4.	4.	89
Cabbage, L. L. F. Dutch	3	9	100	51.	51.	89
Cabbage, E. Fr. Oxheart	4	9	100	12.	12.	89
Cabbage, E. J. Wakefield	3	14	100	58.	58.	89
Sprouts, Brussels	4	4	100	1.	1.	89
Parsley, Dbl. Curled	0	0	100	0.	0.	26
Cucumber, W. Spine	3	6	100	46.3	46.3	85
Beet, W. Sugar	5	19	100	72.5	72.5	*133
Asparagus, Colossal	0	0	100	0.	0.	90
Onion, Mammoth Silver King	0	0	100	0.	0.	85
Borecole	3	9	100	39.	39.	89
Watermelon, Ironclad	3	9	100	84.	84.	89
Tomato, K. of Earlies	2	6	100	89.5	89.5	94

DISCUSSION OF TABLE.—The above seeds were purchased in retail packets, and were sold at the same price as fresh seed. The discolored packets and the lustreless seeds suggested that they were stale seeds, and the test fully confirmed the suspicion. The retailer subsequently acknowledged that these were old seeds, and claims that they were sold to us by mistake. The packets in which these seeds were put up were marked "Warranted," but neither the grower nor the retailer have offered to refund the money paid by us for the seeds.

*Ordinary beet seeds, or more properly fruits, contain from one to seven germs.

GARDEN SEEDS—BOUGHT IN RALEIGH, N. C.

Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality, per cent.	Valuation, per cent.	Vitality of good seed of species named should be
Cabbage, E. J. Wakefield	3	9	100	34.5	34.5	89
Cabbage, L. L. F. Dutch	3	9	94	32.	32.	89
Cabbage, Henderson's E. Summer	3	9	100	53.	53.	89
Cabbage, E. Jersey Wakefield	3	9	66	28.5	28.5	89
Cabbage, E. Cannon Ball	9	9	100	12.	12.	89
Cabbage, Fottler's Brunswick	6	9	100	5.5	5.5	89
Cabbage, Surehead	5	9	100	33.	33.	89
Cabbage, Short-stem Drumhead	3	9	100	57.	57.	89
Cabbage, E. Deephead	4	10	100	44.	44.	89
Squash, R. China	3	9	100	39.5	39.5	89
Cucumber, Giant Pera	3	9	100	94.	94.	86
Muskmelon, Bay View	2	9	99	75.5	74.7	90

DISCUSSION OF TABLE.—The above seeds were put up in packets and were sold at the price of fresh seeds of the same kind. The packets were very much discolored, and showed the effects of much handling. The seeds lacked lustre, and some were badly weevil-eaten. It must be remembered that a laboratory test is always more favorable than a field test would be, and it is most probable that not one seed out of one hundred of the stale cabbage seeds would produce a good plant.

The following extract is from a recent bulletin furnished the State press by the North Carolina Experiment Station:

This Station last month reported the serious adulteration of bran with cockle, cheat and other weed seeds, and the inevitable result of feeding the bran, by which a clean field would rapidly become seeded with these obnoxious weeds, wherever the manure was put on the land.

A correspondent from Robeson County sends a seed package which reads as follows:

LATE CABBAGE.

Recommended by U. S. Agricultural Department as the best cabbage for the Southern States. Grown and warranted by the Junaluska Seed Co., Junaluska, N. C. Price, ten cents.

Our correspondent writes: "Sometime in the early part of this spring an unknown man passed through this part of the State selling garden seed, and sold quantities of them throughout the county, but they have proven to be spurious and of no value to those who purchased them. Inclosed you will find one of the papers, also one of the plants. Can you tell us what it is? Thinking or believing it was all right, none of us asked the man his name, and have no redress."

The plant sent by him was apparently the European wild cabbage used often to adulterate cabbage seed. A communication was at once sent to a reputable seed house in western North Carolina, and a reply was promptly received saying: "We hope you can help us run the rascals down. We have heard nothing from them this season, but last year we had many complaints from the eastern part of the State and a friend sent us a seed bag. It was printed 'Cabbage Seed, grown by the Reems' Creek Seed Garden Co.' We investigated the matter and found the parties had lived near Asheville, N. C., but could not get their names to publish them. We think the Junaluska concern the same parties that swindled the people last year."

The rascals are smart, because they do not give their names. The post-offices Junaluska, N. C., and Reems' Creek, N. C., are purely fictitious, for there are not now and never have been post-offices by those names.

Out of numerous samples of Kentucky blue grass tested at this station, we have found the large majority to germinate less than 7 per cent., the highest being 20 and the lowest 0 per cent. These seed samples were in almost every case very foul, containing besides much timothy (a good but much cheaper seed), dirt, sticks, hairs, and various weed seeds. Johnson grass seed as sold in this market rarely germinates above 15 per cent., though good seed should germinate 75 per cent.

Red clover is usually the foulest seed sold in the market. Most of this seed is gathered by local merchants and sold without cleaning, thereby being the medium for scattering broadcast such pestilent weeds as plantain, wild carrot, daisy and others. Clover seed often contains considerable amounts of adulterations such as sand and quartz rock.

Other State Experiment Stations, notably Iowa, Delaware, and Connecticut, have found on their markets much weed-infested seed.

But aside from preventing carelessness in preparing seeds for the market and rendering deliberate frauds easy of exposure, there is a large field for usefulness of a testing station in educating the seed-using

public to appreciate exact scientific methods in mixing and sowing seeds, and the superior economy of purchasing only high-grade seeds. The seedsmen are not wholly to blame for the badness of much of the seed on the market. So long as farmers and gardeners demand cheap seeds, regardless of quality, just so long will persons be found to cater to the demand, even though they are obliged to debase the quality to make up for the low price. Very cheap seeds should be always viewed with suspicion. They are usually the most expensive things that the farmer can buy. Concerning cheap seeds, Dr. William Carruthers, Botanist to the Royal Agricultural Society of England, in a report to that body, remarks: "It is impossible to estimate the injury that an agriculturist does to himself when, to save a few shillings in the spring by purchasing inferior seed, he insures at harvest a crop not only poor in itself, but abundantly mixed with seeds of worthless and noxious weeds, whose injury to his crops does not end when they are cut down with the grain. In buying foul seed he is acquiring material which may prove a serious injury to his crops for years to come."

The farmer who buys such seed loses not only the present money he invests in the purchase of seed and fertilizers, and in the preparation of the land, but also the value of the increase he might reasonably have expected. But this is not all. The cost of eradicating the weeds whose seeds he has unwittingly purchased and sown with the so-called cheap seeds, and the injury they do to his succeeding crops, must also be considered. One sample of clover seed recently examined at this Station contained over five per cent. of dodder seeds. The dodder is a parasitic plant which feeds upon the juices of clover and related plants. It is extremely difficult to get rid of when once introduced into a field. Its seed have been known to sprout after having been buried in the earth for four or five years. Oftentimes newly seeded clover fields may be seen in which there appear to be more plantain, sheep sorrel, daisy and carrot than clover. The old problem of the different possible ways in which wheat may turn to chess is still discussed where farmers meet. These things will continue to be as long as low-grade seeds, containing weed seeds, are sold and sown.

But there is another side to the question. Unless the farmer knows the quality of the seeds he proposes to sow, his calculations are, at best, mere guesswork. He has no rational basis upon which to calculate. He cannot make a rational mixture of seeds, so as to give a definite proportion of the bearing capacity of the land to each species. He cannot tell which species of a mixture will furnish the bulk of the herbage. Yet he cannot afford to sow upon land brought at great expense to its maximum point of productiveness, seeds of whose quality he knows nothing, and for whose quality the seller distinctly repudiates all responsibility.

The following guarantee is printed in the catalogue of one large English seed firm, and is substantially the same as that given by all

English guarantee houses, who have a "private contract" with some seed-testing station:

1. "Our seeds are sold, guaranteed pure, clean and of the percentage of vitality named in our catalogue.
2. "This guarantee is subject to the analysis of the Botanist of the Royal Agricultural Society.
3. "If the result of the analysis does not confirm the above guarantee, we will take back the seeds and pay cost of carriage both ways, but seeds must not be sown before making complaint.
4. "The seeds once sown, our responsibility ceases. The result depends upon so many things besides the quality of the seeds that the growth cannot be guaranteed."

Contrast the above rational and civil treatment of customers with the following disclaimer, which is printed, with some variations, in the catalogues of most non-guarantee houses:

"We wish to be distinctly understood that, although we continue to take all possible pains to supply only new, genuine and unadulterated seeds, yet we still give no warranty, express or implied, as to description, quality, productiveness, or any other matter, of any of the seeds we send out, and will not be in any way responsible for the crop. Every order received for articles named in this catalogue will be executed on these conditions only."

2.—SEED TESTING IN THE UNITED STATES.

Until about nineteen years ago no serious attempts were made in the United States to investigate the quality of feed stuffs, fertilizers or seeds sold to farmers, although European countries, notably the German States, have had experiment and control stations doing practical and useful work in this line for forty years. In the United States prior to the financial panic of 1873 the conditions were not favorable for inaugurating scientific, exact and economical farming. With a favorable climate, an almost virgin soil, easy transportation, high prices, slight competition and the world's markets in which to sell, the American farmer seemed to be the spoiled child of nature. He felt above the necessity for economy, or was engaged in pioneer work to which the maxims of economy do not always apply. About the date named, or a little before, the inevitable result of our former methods of farming began to be felt, and the feeling has grown more acute each succeeding year. That there were and are still other factors at work sapping the American farmer's prosperous estate is undeniable, but these need not concern us here. The farmer's troubles have sufficiently taught him the value of exact and economical methods. He is now anxious to learn how to restore the fertility of his depleted soil by means of rationally-compounded fertilizers, improved methods of tillage and rotation of crops, cleaner and better seeds, etc. The rapid increase of the commercial fertilizer trade with its occasional exposures of fraud soon showed the desirability of bringing in chemical skill to control this trade and prevent imposition on farmers.

Later there developed a similar desire for the investigation of the seed trade and of the quality of seed being offered for sale. Since

the establishment of the experiment station system in the United States more or less work in this line has been done by different stations. The first station conducting seed tests in America was the Connecticut Station in 1877, two years after its establishment. Soon thereafter, February 21, 1879, seed investigations were commenced at the North Carolina Experiment Station, the work having been done under the direction of Dr. Albert R. Ledoux, who imported the methods and apparatus used in some of the German Stations. The work begun here in 1879 has been continued in connection with various other lines of botanical investigation at the Station and a vast amount of data has been accumulated, some of which has already been published. For details of this work, see Bulletins 59, 63, 67, 73.

Very early in the investigation into the quality of the seeds in the market, the need of an exact and determinate standard of quality was felt. An attempt to elaborate such a standard soon showed the futility of ordinary field or soil tests over which the investigator has little or no control. A determinate standard must be based upon exact, accurate and controllable methods such as can be carried on only when all the factors concerned in setting into activity the vital energy of the seed—heat, moisture, light, oxygen, etc.—are fully under control. The only practicable and useful standard possible is a Laboratory Standard.

This point in our investigation was reached in 1889, and it was thought best to attempt to enlist the more enterprising seedsmen in the subject. To this end, in the spring of that year a circular* was sent out to all the larger seed firms in the United States and to many in Europe. Following the preliminary notice subjoined the circular contained three pages of plant names, including all the more important field, garden and flower plants. Concerning these seeds was asked the following questions:

1. What percentage by weight of impurities should be allowed in a choice sample of this seed?
2. What percentage of viability should be required?
3. What is the maximum age to be allowed for commercial samples of such seed?
4. What is the maximum, minimum and optimum temperature for germinating this seed?

To this circular the Station received about 120 answers. Some of the oldest and best-known seedsmen in the United States, England, Germany and Switzerland furnished very complete and detailed answers which have since proved of the utmost value in the seed work carried on at this Station. All of the replies except those of the Control Stations in Germany and Switzerland showed, however, the impossibility of securing exact and comparable data from diverse and empirical methods. By combining such reports as were not conflicting and elucidating others by special investigations carried

*See Appendix for circular.

out for that especial purpose, we have been able to collate the majority of these reports, and with such additions as we have ourselves abstracted from the records of this Station, the data is now presented to the public in the following pages.

There has been considerable discussion as to whether the European system of seed control is practicable or desirable for this country. It would seem plain to average people that any system which discourages carelessness and roguery, which stimulates enterprise and zeal, and protects honest traders against the unscrupulous ones is worthy of adoption until a better can be found.

3.—THE SEED CONTROL SYSTEM IN EUROPE.

The idea of controlling the quality of seeds offered for sale in the market by scientific methods is not new. The first institution for testing the quality of commercial seeds, according to modern scientific methods, was established at Tharandt, in Germany, in 1870. Since then similar institutions have been established in nearly all the States of the German Empire, and in Austria, France, Switzerland, Italy and Denmark. In England, the Royal Agricultural Society employs a skilled botanist to test seeds for members. All of these institutions are controlled by State governments, and are supported partly by grants of public funds and partly by fees. The organization of the different stations consists of a reputable botanist at the head, with a corps of trained assistants.

Seed samples are tested only as to their purity and power of germination, in so far as these facts can be ascertained by botanical inspection, the separation and weighing of foreign matters, and by germinating tests of the seeds in specially constructed apparatus. It is possible for a competent botanist to discriminate between the seeds of most species of plants by microscopic examination, but it is not always possible by this means to distinguish the seeds of mere varieties. Thus a botanist can by simple inspection and without trouble distinguish turnip seed from cabbage or radish seed, but cannot discriminate one variety of cabbage seed from another. This can be done only by actually growing the plants. For testing varieties most European seed control stations have trial gardens, but the genuineness of the variety is not guaranteed or tested except under a special agreement and by payment of a special fee. The germinative power of the seeds is ascertained by actually testing a sample. Usually 400 genuine seeds are taken without deliberate selection from the sample to be tested. These are divided into two equal portions and tested in separate dishes of the apparatus. The average of the two lots is taken for the mean viability of the original sample. Where the difference between the two lots exceeds 10 per cent. the test is discarded and repeated. The purity of the sample is determined by first weighing it and then separating and weighing the foreign matters and calculating their percentage of the whole weight.

The impurities are further separated and weighed according to their specific nature and are usually arranged under three categories—useful seeds, noxious seeds, and inert matter. The real or cultural worth of the sample is found in terms of per cent. by multiplying the purity percentage by the viability percentage and dividing the result by 100. Thus $\frac{\text{Purity} \times \text{Viability}}{100}$ = Real worth. The apparatus used in the different testing stations, though differing more or less in details, is based upon the same principles. The seeds are supplied with the amount of warmth and moisture which experience has shown to be most conducive to the growth of the different species. The tests are therefore always more favorable to the seeds than an outdoor soil test would be. In a country where there are more than one testing station, it is very desirable that the stations shall all use the same apparatus and method, in order that the work of different stations may be directly comparable and serve as mutual checks. The most celebrated seed control station in Europe is located at Zurich, under the patronage and control of the Swiss government. This station has an international reputation and does testing for seedsmen in all parts of Europe. It does not affiliate with the German stations, and its methods differ somewhat from those used in Germany. The methods of the Swiss station are those most applicable to the American social and political system, and to the needs of the American seed trade. By act of the Swiss Federal Congress, all seed dealers, without exception, offering seeds for sale within the confines of the republic, are obliged to have their seeds tested at the Zurich station, and to brand or otherwise mark each retail package with the percentage of pure vital seed as reported by the station.

For foreign patrons the station has two systems—first, the "private contract" by which, for a specified sum per annum, each patron has the right to have a certain number of samples tested for his own satisfaction. Under the private contract system, the Swiss station has no connection with the customers of its patrons. The second system is the "control contract." Under this contract each patron has, as under the private contract, the right to have a certain number of samples analyzed and reported upon; and in addition to this, it has the right to print on its advertisements the legend: "Under control of the Swiss Seed-Control Station." All seeds are sold under a specific guarantee of purity and vitality, and each customer of the control contract patron has the privilege of sending to the station, free of charge, a sample of the seeds bought by him, and if the same falls short of the guaranteed quality, the seller is compelled to give a commensurate reduction in price, or to receive back the seeds, paying carriage both ways, as the purchaser prefers. To protect the dealer from imposition, the customer who proposes to send a sample to the station is required to take the same, in the presence of two responsible and disinterested witnesses, from an unbroken package sent by the seller, and this sample must be bagged, sealed and mailed

in the presence of the same persons, who sign a certificate to that effect, which is mailed to the station with the letter of instruction.

The "control contract" system is preferred by Swiss seedsmen and by most houses within a reasonable distance of Zurich; the "private contract" system by those more remote. In a list of its patrons published in 1888, the Swiss Station gives the names of twenty-four foreign houses as having private contracts, of which ten are in Germany and eight in Great Britain. During the year 1893 more than 150 seed firms had private contracts with the Zurich Station.

With a view to ascertaining the result of the control system in Europe, the North Carolina Experiment Station some time ago sent to each of these contract houses a circular of inquiry. Replies were received from all, and, without exception, were favorable to the system. The following are extracts from a few of these replies—those originally in German or French being here translated:

Carl Seibenmann, Basle, Switzerland.—"Ours is a wholesale house under a 'control contract' with the Zurich Station. We sell cheap non-guaranteed seeds to those who want them, but the majority of our customers, which are associations of farmers, demand controlled seeds. It is indisputable that the control system is of great importance and has done immense good, especially in the trade in agricultural seeds. It is known to us that formerly many merchants sold seeds with very little vitality, and clover seed which was adulterated with spurious kinds and with stained quartz grains. By such means these merchants were able to undersell honest houses, to the detriment of agriculture."

Kent & Bryden, Darlington, England.—"We have a 'private contract' with the Zurich Station. The advantage is that in purchasing seeds in bulk which may be of doubtful quality, we are able to send a sample to Zurich and quickly get a reply, stating the purity of the sample and whether it appears to be of good quality, and later we get the full report of the test. The seeds sold in this market have greatly improved in quality since purchasers have demanded guaranteed seeds. We believe it to be of very great importance to have a standard of quality. If such were established, seeds could be bought and sold by it. We offer all our seeds subject to the standard adopted by the Royal Agricultural Society of England."

David Allister, London, England.—"I have a private contract with the Station at Zurich. The advantages of such an establishment to agriculture and to seedsmen is very great. Many kinds of seeds have improved since the establishment of the testing stations. Especially is this noticed in grass seeds, such as meadow fox-tail, meadow fescue, cock's-foot, sweet vernal, rough-stalked meadow grass, etc., which formerly were either greatly adulterated or had other seeds wholly substituted for them. Seedsmen now vie with each other in procuring the finest and truest qualities of seeds, and the percentage of purity and vitality being ascertained through the testing stations, they *guarantee* them to their customers."

Wallich-Swansfeld, Inspruck, Tyrol.—"I have a private contract with the Zurich Station since 1887. I sought this to increase the confidence of the public in my seeds and to protect myself in purchasing. I think the Swiss Station is not excelled in its line of work. The quality of seeds in the market, especially clover seed, has improved every year since the establishment of control stations in the different countries of Europe. I would not require merchants to sell seeds of any fixed quality, but only to guarantee a definite quality under regulations similar to those established by the Swiss Station at Zurich."

Laroye & Vankerschoffer, Ostend, Belgium.—"We have a private contract with the station at Zurich. The advantages of such a station are multiple. By this means we are able to learn the quality of seeds we propose to buy, and thus protect ourselves and our customers. Purchasers now have greater confidence in the seeds they buy of us. The 'control contract' system of the Zurich Station has even greater advantages, but the conditions are onerous. The quality of seeds in the market has, in effect, improved since the advent of the testing stations, the

samples being now much cleaner. We have also better machinery than formerly for cleaning seeds, but this is also, in part, due to the educational work of the seed testing stations."

J. Lambert & Son, Frier, Switzerland.—"We have a private contract with the Zurich Station. We think it is a very good thing, because it gives us an advantage in selling seeds to consumers and to other merchants. The seed trade has been carried on in a very bad and unfortunate manner, and until recently there was no real security for the purchaser, whether the seeds were good or bad."

Agricultural and Horticultural Association, London, England.—"We have a private contract with the Zurich Station. We get reliable tests at reasonable rates, and have found every detail complete and satisfactory. There has been very great improvement indeed since the guarantee system of selling seeds came into use."

The following from the manager of the Association is of interest:

"DEAR SIR: We are glad to hear that an interest has been aroused in North Carolina upon the question of the quality of seeds. The custom of guaranteeing seeds is sufficiently well established to show that it is possible for all respectable seed firms to carry out the plan if they are willing to do so. It is true that a very great many seedsmen hold back from giving guarantees, but we are quite sure they will be compelled to adopt this method or gradually see the more intelligent agriculturists taking their custom where they can be guaranteed reliability of supply. It is quite true that 150 houses are affiliated to the Swiss International Testing Station at Zurich, and we should say the majority of these give guarantees to their customers, although very likely they do not all do so. On the other hand, a good many houses sell on guarantee who are not affiliated to the Zurich Station. In this case they guarantee according to the tests of Professor Carruthers, of the Royal Agricultural Society, Professor McAlpine, of the Highland and Agricultural Society, or other acknowledged authority.

"If your farmers and landowners are wise they will support the movement you have commenced; and if the seedsmen prove obstinate, then the agriculturists could not do better than copy the example of the British agriculturists, who have established this Agricultural and Horticultural Association for co-operative supply. For your information, I may mention that our Association now numbers nearly 3,000 members, has a business approaching £80,000, or $390,000, and is progressing in a most satisfactory way. It is worked upon the plan of sharing profits with the employees and the customers, the latter being the proprietors. Yours faithfully, EDWD. OWEN GREENING."

James Hunter, Chester, England.—"I introduced the guarantee system into England in 1882, and since then several of our largest seed firms have adopted the system, and very marked improvement in the quality of seeds has taken place."

Dickson's Seed House, Chester, England.—"We clean our seeds to the greatest attainable perfection, and guarantee them to our customers to be of the percentage of purity and vitality stated in our catalogue, and sell them subject to the analysis of the consulting botanist of the Royal Agricultural Society."

James Carter & Co., London, England.—"We guarantee our seeds, according to the quality purchased, to be of the highest average vitality of the season, and it is open to any purchaser to submit them to professional analysis."

Dr. William Carruthers, Botanist Royal Agricultural Society, London, England.—"During the past year, 1890, I have examined for members of the Royal Agricultural Society 341 samples of seeds. The general result noticed is a continual improvement in quality, but it is apparent that a great deal of utterly bad seed still finds its way into the hands of farmers. The purchaser of seeds should obtain from the vendor, by invoice or otherwise, a guarantee that the sample contains not more than a specified amount of other seeds, and that it is free from ergot and dodder, and a statement of the percentage of seeds that will germinate. The council of the Royal Agricultural Society strongly condemns the purchase of ready-mixed seeds for grass land."

J. L. Beney, Valleyres, Switzerland, President Agricultural Society.—"We are very much satisfied with the control of seeds exercised by the Experiment Station at Zurich. It renders great services to our agriculture."

Raynbird & Co., Basingstoke, England.—"Ours is a private contract with the Zurich Station. We sell our seeds with a specified and guaranteed percentage of purity and germinating power. We send herewith our last price-list of field seeds, which will show what we mean. We have the most improved machinery for cleaning seeds at our mills, and send out only the best obtainable samples."

Damann & Co., San Giovanni, Italy.—"We do not hesitate to declare that a seed control station like that of Zurich would be a great advantage both for the seller and the buyer of seeds, since it would be equally valuable to both to know exactly what they are offering and buying."

Fratelli Ingegnoli, Milan, Italy.—"We have a private contract with the Seed Control Station in Zurich, Switzerland. A guarantee of the purity and vitality of seeds we regard as of vital importance. For certain grasses the purity may be approximately judged by visual inspection, but the germinative power can be determined satisfactorily only at a botanical station. We have a government station for control of seeds at Modena, Italy, but we prefer to have our seeds tested at Zurich, because that station has a world-wide reputation for the thoroughness of its work."

H. Keller & Son, Darmstadt, Germany.—"We have had a private contract with the Station at Zurich for about five years. The advantages offered by a station as well conducted as the one in Zurich are very great. The Zurich Station is the most trustworthy and careful of all the stations in Europe, and has had the most experience. The different European stations proceed by different methods, and the result is that each station, from one and the same lot of seeds, obtains different results. Germany has a large number of seed control stations, among which the better known are those in Tharand, Kiel, Breslau, Bonn, Münster, Karlsruhe, Darmstadt, and Hohenheim. There is also a control station in Vienna, Austria. There can be no reasonable doubt but that the seeds in commerce have greatly improved since the establishment of test stations, about ten years ago. We think the guarantee system of the greatest value to the seed trade, but it is our judgment that the test stations should be private establishments and that governments should not establish a minimum grade or standard for seeds."

Jacob Morel, Sins, Switzerland.—"Ours is a control firm under the regulations of the Zurich Station. We quote you the following guarantees as published by us in our last catalogue:

	Purity.	Vitality.
Trifolium arvense	98 per cent.	93 per cent.
" pratense	96 "	95 "
" hybridum	94 "	70 "
" repens	96 "	93 "
Medicago Sativa (Provence)	97 "	90 "
" lupulina	99 "	62 "
Festuca pratense (German)	95 "	92 "
Alopecurus pratensis	85 "	70 "
Agrostis stolonifera (American)	96 "	88 "
Phleum pratense	99 "	97 "
Dactylis glomerata	56 "	78 "
Arrhenatherum avenaceum	74 " / 90 "	72 " / 75 "
Lolium Italicum	97 "	80 "
Lolium perenne	98 "	93 "
Avena flavescens	96 "	42 "

4.—THE METHOD OF SEED CONTROL.

The long experience and international patronage of the Swiss Seed Control Station at Zurich seems to show that the "private contract" or voluntary guarantee system is practically as efficient as the legally enforced State control system established in Switzerland. When seed merchants find a public demand for a definite guarantee of the purity and viability of seeds, the more enterprising seedsmen will be only too glad to meet the demand, and the others, doubtless, will soon follow. All that is necessary is a definite published method of analysis by which seedsmen may buy as well as sell. This attained, the goods of competing seedsmen will be sold upon their merits, and honest and careful merchants will not have to compete with those who are neither honest nor careful.

The following outline of a scheme for voluntary co-operation between the experiment stations, representing the general public, and the seed trade for mutual benefit, is offered tentatively and subject to emendation:

1. The Association of American Experiment Station Workers to adopt a standard form of apparatus and process for examining and testing seeds, and the use of these to be obligatory on all stations publishing work in seed testing. No changes to be made in apparatus or method until the same has been authorized by the Association or a committee of the same.

2. Seedsmen entering into the agreement to be furnished, at their own cost, with the official apparatus and methods, and they to test their own seeds or have them tested according to the official process by private or public testing stations, and to guarantee a definite and stated percentage of viability, purity and "real worth" according to the official method.

3. Leguminous seeds are, in addition, to be guaranteed to be free from dodder, cereals to be free from cockle, and rye seed to be free from ergot.

4. A purchaser of seeds to be allowed to take from any package in the presence of a disinterested and reputable witness a sample, and seal and mail the same to the Experiment Station of the State in which purchaser lives. The sample for testing must be taken according to the official method and a certificate to that effect must be signed by the aforesaid witness and mailed to the station with the sample. If the station's test shows the sample to fall more than 5 per cent. below the guaranteed "real worth," the seedsman making the guarantee to make a commensurate reduction in price or receive back the seeds, paying carriage both ways, as purchaser may elect. The seedsman is always entitled to a margin of five per cent. to allow for the possible error of analysis.

5. Where seedsmen guarantee the varietal genuineness of their seeds, samples for testing must be large enough to furnish 100 viable seeds in addition to those required for the germinating test. Where seeds prove untrue to name, the seedsman to reimburse the purchaser to the full amount guaranteed.

6. The guarantee given by the seedsman to cease with the sowing of the seed, or after thirty days from the day the seeds were received by purchaser.

The above outline is substantially that which has for some years been in operation by several large English seed firms who are affiliated with the Zurich Seed Testing Station, and who guarantee the quality subject to the analysis of the Botanist of the Royal Agricultural Society of England. This scheme, while affording ample protection to the public, seems to be entirely fair to the seedsmen, and should therefore be welcomed by the honest and more progressive members of the trade.

It has been objected that the seedsmen have no voice in determining the honesty and competency of the men who do the testing in the stations. It is of course possible that a station may have incompetent workers and publish untrustworthy work, but where all the stations use the same method, the work of each acts as a check upon the others, and stations doing untrustworthy work will quickly be recognized and their work stigmatized with merited discredit.

It may be assumed that honest and careful seedsmen will be glad to receive the protection that this plan offers in exposing and publishing the operations of irresponsible dealers, and that they will voluntarily co-operate with the stations. By making such tests, and annually or more frequently publishing the results, the public will soon come to see which seedsmen offer the best goods for the money, and these will soon monopolize the bulk of the trade.

[The complete bulletin contains seventy-six pages, and the subject-matter can be seen by reference to the table of contents on page 348. Persons who do not receive pages 361-416 can be supplied by making application to DR. H. B. BATTLE, Director, Raleigh, N. C.]

II. THE PHYSIOLOGY OF THE SEED.

1.—THE STRUCTURE OF THE SEED.

All of the higher class of plants—the *phanerogama* or *spermaphyta*—the plants which form the staples of agriculture—propagate their species by seeds. The seed is a special structure, always developed in a closed pouch or ovary, which is usually termed the fruit. The seeds of phanerogams are produced by the union of two sexually distinct organs, or as some call them *plants*. The first is the female organ, or plant, which is produced from a self-fertilized egg and eventually developes into the endosperm or food reserve of the seed; the second or male part is produced from a cross-fertilized egg and

Fig. 1. EMBRYO OF HORSE BEAN.

A. Embryo with one cotyledon removed to show root and shoot buds; *c.* remaining cotyledon; *w.* root bud; *k. n.* shoot bud; *s.* testa or epidermis.

B. Germinating seed; *s.* testa; *n.* hilum; *st.* petiole of one cotyledon; *k.* flexure of epicotyledon; *hc.* hypocotyledon stem; *h.* the main root; *ws.* tip of main root; *kn.* axillary bud of cotyledon.—*After Sachs.*

Fig. 2. LONGITUDINAL SECTION OF THE SEED OF INDIAN CORN, magnified six diameters.

c. epidermis or testa; *n.* place where the "silk" was attached; *fs.* base of seed; *eg.* yellow and dense portion of endosperm; *ew.* white and spongy portion of endosperm; *sc.* scutellum or "mouth" of embryo through which it absorbs the endosperm; *ss.* tip of scutellum; *e.* epithelium or skin of embryo; *k.* shoot bud; *w.* (below) root; *w.* (above) prop roots; *ws.* root sheath; *st.* first internode of shoot.—*After Sachs.*

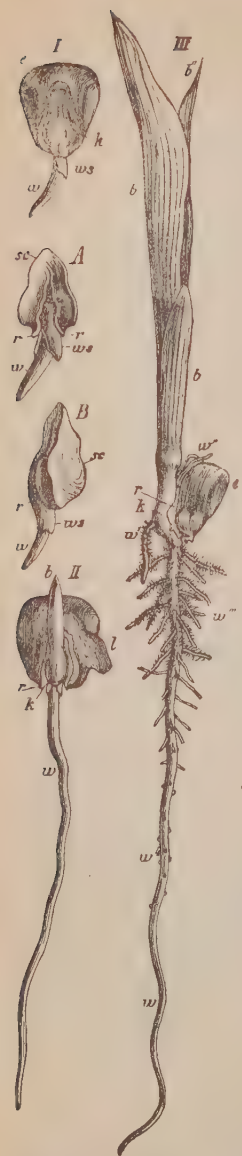

Fig. 3. A SEED OF INDIAN CORN, in three different stages of sprouting.

A. Front view. B. Side view; *w*. main root; *ws*. root sheath; *w*. *w'*. *w'''*. prop roots; *e*. part of seed containing endosperm; *k*. shoot bud; *sc*. scutellum of embryo; *r*. *r*. the open "mouth" or scutellum; *b*. *b''*. *b'''*. first leaves of plant.—*After Sachs*.

developes into the germ, kernel or embryo of the seed. During the process of ripening of the seed or during its germination the kernel or embryo consumes the endosperm.

A good example of a seed in which the endosperm is consumed by the germ during the ripening process is the common garden bean. An example of a seed in which the endosperm is consumed during germination is the Indian corn or maize. See Figures 1, 2 and 3.

Spermaphytes are still further divided into two classes, distinguished by the number of cotyledons, or seed leaves, which the embryo possesses. Most of our hardy shrubs and herbs belong to the dicotyledonous class. The cereal grains, grasses, and garden flowers of the lily tribe belong to the monocotyledonous class. The conifers have more than two cotyledons—usually five or seven.

The exterior form of seeds and the appendages for procuring their dissemination are almost endless, but these do not concern us here.

2.—THE GERMINATION OF SEEDS.

The mature seed, removed from the various envelopes, pod, capsule, pome, etc., in which it was concealed and nourished by the mother plant, resembles a lifeless object, but when subjected to a certain temperature in the presence of sufficient oxygen and moisture it will, in a period amounting for most plants to only a few days, swell, burst its covering and push forth first the root and then the shoot axis. The root axis instinctively grows downwards or away from the light, and the shoot axis upwards or towards the light. The force or intelligence which sets the dormant seed into motion and directs the growth of these organs is variously called "irritability," "life," etc., but this is an explanation which does not elucidate. Whatever the nature of the controlling power may be, it is liable to be lost without any apparent change in the outward form or organs of the seed. We know, however, that the moisture absorbed by a mature and viable seed, when the

temperature is favorable, first dissolves part of the starchy food reserve which is changed by a ferment, diastase, also contained in the seed, to sugar, and this is absorbed by the root and shoot buds of the embryo causing them to elongate and grow—in other words, the seed germinates.

The presence of sufficient moisture to cause the seeds to swell is the first and most fundamental requirement. Many experiments have been made to discover whether pure water or aqueous solutions or mixtures of various chemicals are best to hasten the germinating process. Nobbe, in his *Handbuch der Samenkunde*, p. 102, *et seq.*, details many experiments in this line, the results of which showed that pure distilled water causes the most rapid swelling, and consequently the quickest germination of the seed.

The nature of the outer seed coat or *testa* of seeds differs more or less in different plant families. In the *Leguminosæ*, or pulse family, the seed coat is often so hard that mature and viable seeds often remain unsprouted in the ground for years. Out of a sample of 1,000 seeds of kidney vetch placed by Professor Nobbe in a moist chamber, kept at a constant temperature of from 65°F. to 70°F., while 840 seed had germinated after the expiration of 36 hours, the last viable seed germinated only after 260 days. Under like circumstances a sample of red clover gave 90 per cent. of germinated seeds in 24 hours, but the last viable seed germinated only after 156 days. It is an interesting question how much water, compared with the weight of the seed itself, a seed requires to start the growth of the embryo or begin the sprouting process. Experiments by Nobbe, Sachs, Hoffmeister, and other European botanists, show that the seed must be quite saturated by water before the germinating process begins. To completely saturate the seed with water requires for some species, *e. g.*, the horse bean (*Vicea Faba*), 157 per cent. of the dry weight of the bean itself. Hoffman (*Landw. Versuch-Stationen*, VII., p. 47) gives the per cent. in the first column of the following table, the figures in second column are those given by Nobbe in the *Handbuch der Samenkunde*. Some experiments in this line at the N. C. Station agree most closely with Nobbe's figures.

Genera of Plants.	Water absorbed in swelling, in per cent. of dry weight of seeds.	
	According to Hoffman.	According to Nobbe.
Wheat	45.5	60.0
Barley	48.2	----
Rye	37.7	----
Oats	39.8	----
Buckwheat	46.9	----
Corn	44.0	39.8
Millet	25.0	----
Peas	106 8	96.0
Horse Bean	104.0	157.0
Vetch	75.4	----
Lucerne	56.0	87.8
White Clover	126.7	89.0
Red Clover	117.5	105.3
Rape	31.0	48.3
Hemp	43.9	----
Sunflower	56.5	----
White Beet	62.5	51.8
Sugar Beet	120.5	----

As a rule the smaller oleaginous seeds and cereals have the least water-absorbing capacity, while the legumines have the greatest.

3.—THE PROXIMATE COMPOSITION OF THE ENDOSPERM.

Many analyses of the endosperm, or food reserve, of seeds show it to be a very complex substance. The nitrogenous portion in most seeds is in the form of gluten-fibrin or gluten-casein, which is insoluble in water, but completely soluble in dilute solutions of acetic acid, hydrochloric acid, tartaric acid, malic acid and citric acid, and in dilute solutions of potash and soda. *Gliadin*, another component of the albuminous part of cereal seeds, is fully soluble in all the above-named media, and slightly soluble in pure water. *Mucedin*, the third component of cereal albumins, is fully soluble in water. Different families of plants possess peculiar forms of albumin; for example, the legumines have *legumin*, which differs from *gliadin* by a higher content of sulphur.

The non-albuminous part of the endosperm is composed chiefly of starch, oil, and parenchyma. Starch plays a very unimportant role in the composition of the ripe seeds of most agricultural plants. It occurs as a transitional constituent in the growing seed, but disappears in the ripening process. According to Naglei, in about nine-tenths of all the natural families of plants, the ripe seed is free from starch.

4.—THE MINERAL CONSTITUENTS OF THE SEED.

The mineral part of the ripe seed forms but a very small per cent. of its total weight.

The following table of ash analyses of seeds is from Dr. Emil Wolff, except the cotton and tobacco, which are from records of the N. C. Experiment Station:

Seed of Plants.	Ash.	Pot-ash. K_2O	Lime. Ca O	Phos. Acid. P_2O_5	Silica. $Si\ O_2$	Mag-nesia. Mg O	Sul-furic Acid. $S\ O_3$
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Winter Wheat	1.97	31.16	3.34	46.48	2.11	11.97	0.37
Spring Wheat	2.14	29.99	2.93	48.63	1.64	12.09	1.52
Rye	2.09	31.47	2.63	46.93	1.88	11.54	1.10
Oats	3 14	27.96	7.46	47.73	1.16	10.12	....
Indian Corn	1.51	27.93	2.28	45.00	1.88	14.98	1.30
Buckwheat	1 37	33.07	4.42	48.67	0.23	12.42	2.11
Peas	2.73	41.79	4.99	36.43	0.86	7.96	3.49
Beans	3.57	31.90	6.38	35.52	0.57	7.62	4.05
Vetches	3.10	30.14	8.03	37.55	1.31	8.95	3.69
Lupines	3.95	29.84	8.90	41.97	0.42	11.64	4.31
Red Clover	4.50	35.35	6.40	37.93	1.30	12.90	2.40
Rape	4.44	24.50	4.18	42.33	1.42	11.80	2.39
Flax	3.69	30.63	8.10	41.50	1.24	14.29	2.34
Cotton	3.53	33.90	6.68	31.05	0.07	15.82	5.83
Tobacco	3.15	28.40	3.60	39.36	0.40	21.84	1.59

The above table is valuable as showing the mineral matters essential for maturing viable seeds, the amount of each ingredient removed from the soil, and the comparative quantities in which these are required.

5.—THE EFFECT OF TEMPERATURE ON THE GERMINATION PROCESS.

Seeds are very sensitive to the effect of temperature, both while they are growing and while dormant. As regards dormant seeds, it makes a great difference whether dryness or moisture accompanies heat. Soft seeds, whose cells are full of sap, can stand much less variation of temperature than harder and drier seeds. The limits of temperature within which the seeds of different genera of plants will retain their viability has been experimentally determined by Sachs, Hoffmeister, Nageli, Nobbe, and other European and American botanists. The general agreement is that in ordinary dry air well ripened seeds will endure, unharmed, almost any ordinary fall of temperature, at least as low as —40°F. At the other extreme the larger and drier seeds, *e. g.*, cereals, beans, peas, etc., are able to withstand a dry temperature of 212°F., or above for a short time. Seeds which

have been exposed to an extraordinary high temperature within the limits of their resisting power, according to Nobbe, germinate more quickly than similar seeds not so exposed. When dormant seeds are exposed to a moist heat, *e. g.*, at 138°F. for above ten minutes most small seeds have their viability destroyed; larger seeds, such as Indian corn, beans, etc., may withstand that temperature for fifteen minutes with the loss of from 40 to 70 per cent. of the seeds. The genus *Cytisus*, however, will withstand a temperature much higher, and in practice it is customary, before sowing such seeds, to throw the seeds into boiling water just removed from fire and allow them to remain therein until the water has become cold. All cereal seeds are rendered unviable by a moist temperature of 150°F., enduring as long as five minutes. A constant temperature of 95°F. in water, or 105°F. in moist sand will destroy the germs of all cereal, and most other seeds, in a few days. The ordinary summer temperature of the moist low lands of the South Atlantic and Gulf coasts is alone sufficient to destroy the viability of many species of seeds during one season.

There is for each genera of seeds a maximum moist temperature above which the embryo suffers, first, a hindrance of development and then disorganization. There is, likewise, a minimum temperature below which similar results occur, but the death of the embryo is more certain to follow upon excess than deficiency of heat. So long as the cell walls are not ruptured by frozen sap or moisture, the result of exceeding the minimum temperature is simply to delay the development of the embryo while this excess continues. There is an optimum moist temperature at which the germinating process is most active. This optimum differs with different species of plants. For most agricultural plants the maximum, minimum and optimum temperatures have been found by actual trial. These are given in the table on page 367, of this bulletin. The figures in this table are in part derived from the records of the N. C. Experiment Station. The figures, except as to flower seeds, have been compared with and in some cases modified to agree with similar tables published by Sachs, Nobbe, Stebler, and other European botanists and seed control stations. The figures for flower seeds, as given in the table, were furnished by the late Peter Henderson, of New York. Owing to the more pressing claims of other work the testing of flower seeds has not been carried far enough at this station to enable us to furnish trustworthy figures wholly from our own records. So far as we have gone, however, we found that Mr. Henderson's optimum temperature was from 5°F. to 10°F. too low, and in making up the table as given his optimum was in all cases increased by 5°F. The following are Sachs' minimum, maximum and optimum temperatures for germinating the seeds named: (See Sachs' *Handbook of Experimental Physiology.*)

Kind of Seed.	Minimum.	Maximum.	Optimum.
Indian Corn	49°F.	105°F.	91°F.
Bean	49°F.	105°F.	91°F.
Pumpkin	52°F.	105°F.	91°F.
Barley	41°F.	100°F.	84°F.
Wheat	41°F.	108°F.	84°F.

To show the greater quickness with which the seed sprouts at higher than at comparatively lower temperature, Nobbe gives the following table. The figures in the different columns indicate number of days in which the seeds remained in the germinating pan before the rootlet appeared, at the different temperatures indicated:

Plant.	Days before seeds began to germinate at different temperatures.			
	40°F.	50°F.	60°F.	65°F.
Winter Wheat	6	3	2	1¾
Winter Rye	4	2½	1	1
Winter Barley	6	3	2	1¾
Spring Oats	7	3¾	2¾	3
Indian Corn	---	11¼	3¼	3
German Millet	---	11⅙	4¾	4
English Ray Grass	10	5½	3¾	3
Tall Oat Grass	9	7¾	4¼	3
Timothy Grass	---	6⅓	3¼	3
Red Clover	7⅓	3	1¾	1
Lucerne	6	3¾	2¾	2
Hop-trefoil	10	7½	4	3½
Lathyrus Sativus	7	3½	2¾	2¼
Faba Vulgaris	7	6½	4¾	4¼
Vetch	6	5	2	2
Pea	5	3	1¾	1¾
White Lupine	5	3¼	---	---
Buckwheat	8	4½	3½	3

The above table shows that for all but three of the genera tested the seed may begin to germinate at a temperature below 40°F. Wheat, rye, barley and seeds of hardy trees, such as the maple, have germinated on cakes of ice and pushed their roots down into the frozen mass.

Haberlandt (*Landw. Versuch Stationen, Band, XVII., 104*) gives the following table showing the number of seeds of each species of plant named, out of a sample of 100 seeds in each case, which sprouted at the constantly maintained temperatures indicated. The moisture supplied to the seeds being in each case sufficient. A series of similar tests was made at the N. C. Experiment Station in 1890, using the Nobbe seed pan. The result in most cases was a lower per cent. of ger-

minated seeds, but as a whole did not differ greatly from Haberlandt's table, the difference noted appearing to be caused by lower grade seeds:

Plants.	Number of Seeds Out of 100 which Sprouted in Number of Hours at the Indicated Temperature.									
	60° F.		77° F.		88° F.		100° F.		111° F.	
	Seeds Sprouted.	In hours.	Seeds Sprouted.	In hours.	Seeds Sprouted.	In hours.	Seeds Sprouted.	In hours.	Seeds Sprouted.	In hours.
Wheat	100	56	100	32	100	48	0	....	0	....
Rye	100	56	100	32	100	80	0	....	0	....
Barley	100	72	92	72	24	144	0	....	0	....
Oats	100	80	100	48	100	80	0	....	0	....
Indian Corn	80	144	68	56	100	48	100	48	12	80
German Millet	100	120	100	48	100	48	100	48	92	72
Timothy	76	168	100	44	88	148	0	....	0	....
English Ray Grass	100	216	100	120	100	72	0	....	0	....
Spurry	100	24	100	32	100	32	60	144	0	....
Vetch	100	48	100	48	100	65	0	....	0	....
Horse Bean	100	120	100	56	100	70	0	....	0	....
Lupines	100	128	100	56	100	48	100	56	0	....
Lathyrus Sativus	100	56	100	24	20	120	0	....	0	....
Crimson Clover	100	32	100	24	100	24	100	24	0	....
Red Clover	100	32	100	24	100	24	100	24	0	....
Lucerne	100	32	100	24	100	24	100	24	0	....
Buckwheat	100	72	100	24	100	24	100	48	0	....
White Mustard	100	24	100	24	100	24	0	....	0	....
Cabbage, late	100	48	100	24	100	48	0	....	0	....
Raddish	100	32	100	24	100	32	100	48	36	96
Carrot	100	152	100	56	100	216	0	....	0	....
Sunflower	100	32	100	32	100	24	100	48	0	....
Poppy	100	24	100	48	12	152	0	....	0	....
Tobacco	100	192	100	108	88	168	0	....	0	....
Squash	100	168	100	52	100	48	100	32	50	72
Cucumber	76	216	100	96	100	32	100	48	60	120
Muskmelon	4	290	100	120	100	48	100	48	20	96
Flax	100	32	100	23	100	47	0	....	0	....
Hemp	100	80	100	62	100	48	100	32	100	48

6.—THE ACTION OF LIGHT AND ELECTRICITY UPON THE GERMINATION OF SEEDS.

That the action of direct sunlight is distinctly detrimental to the germination process has been long known. Ingenhouse, in the last century, exposed seeds of the same species to the full sun light and to various degrees of obscured light down to total darkness in a chamber rendered sufficiently moist and warm to germinate the seeds. In every case the seeds exposed to the strongest light sprouted most tardily, while those exposed in complete darkness sprouted soonest. The exclusion of direct light does not imply the absence of air and oxygen, which are necessary to plant activity at all times.

Many experiments have been made from the time of Ingenhouse to Sachs to discover whether or not electricity has any appreciable influence upon the germinating embryo, but in all cases the results have been negative or contradictory. At present this form of universal energy has no value or place in testing the viability of seeds.

7.—THE ACTION OF CHEMICALS UPON THE GERMINATION OF SEEDS.

The generally detrimental action of corrosive chemicals upon sprouted seeds is well known. In practice chemicals may be divided into four classes: (1.) Those which by their corrosive action aid the sprouting embryo to break the protective covering or testa of the seed. (2.) Those which, being poisonous to burrowing grubs or worms, protect the embryo from such depredators. (3.) Those which furnish easily assimilable nourishment for the young plantlet. (4.) Those which destroy the spores of molds already on the seeds. Alexander von Humboldt was the first to discuss and explain the beneficial action of chlorine upon the germination of seeds. (See *Anhang zu Florae Fribergensis*, 1793, p. 156.) Humboldt soaked seeds of peas, cress and other plants in a very dilute aqueous solution of chlorine acid. In this solution the seeds germinated in from six to seven hours, whereas in control tests with water the same varieties of seeds did not germinate inside of thirty-six to forty-eight hours. Water at 46° F. dissolves three times its volume of chlorine; the solubility decreases when the temperature is either above or below this point. Chlorine water of about one-tenth saturated strength, has been used by gardeners to hasten or assist the germination of tender seeds in hotbeds and greenhouses. The chlorinated water is simply sprinkled on the soil after the seeds have been planted. To obtain the beneficial effect of chlorine water, it should be used only in soils free from iron compounds and other heavy metals, since chlorine combines freely with these elements.

The other halogens, iodine and bromine, have much the same action upon seeds as chlorine.

Sulfur in small quantities has a favorable influence upon germinating seeds. Its favorable action is probably due to its destroying the spores of molds upon the seed or in contact with it in the ground or seed-pan.

Arsenic has an energetic and very detrimental action upon germinating seeds.

Antimony has much the same action as arsenic.

The salts of the metallic elements are generally detrimental to the germinating seed. A 5 per cent. aqueous solution of iron sulfate (copperas) will destroy the germs of most seeds soaked in it until saturated.

When the iron salt solution is poured upon sand and seeds afterward sown therein, it requires a 11 per cent. solution to show the evil effects.

Oxid of manganese seems without positive action. Zinc oxid, in a 10 per cent. solution, has a retarding influence upon most seeds.

Lead salts seem wholly without action upon seeds. Bismuth salts are injurious to germinating seed. Copper salts are injurious in all cases and even in very dilute solutions. One gram of copper sulfate in one litre of water (about 15 grains to one quart) retards the germination of most seeds, especially legumines, and in most cases destroys the germinative capacity of one-third or more of the sample. A much more dilute solution is poisonous to the rootlets of recently sprouted plants. Nobbe found that wheat seed, which sprouted 100 per cent. in pure water, in a $\frac{1}{10}$ per cent. solution of copper sulphate gave only 7 per cent., and in a $\frac{1}{2}$ per cent. solution gave no sprouted seeds. With rye he got slightly better results, it requiring a 1 per cent. solution to kill all the seeds.

A 10 per cent. solution of hydrochloric acid in water seems to favor the quick germination of seeds which have been soaked in it for not over two hours. A longer soaking, *e. g.*, 24 hours, or a stronger solution, seems to destroy the life of the embryo.

Commercial sulfuric acid diluted with 16 times its volume of water has a favorable effect upon most seeds soaked therein for 10 to 12 hours. Clover and rape seeds are among those most susceptible to injury by this acid. Nitric acid is detrimental to the life of the embryo. Phosphoric acid, diluted with fifty times its volume of water, has a favorable action upon germinating seed. Oxalic acid, diluted to less than 7 per cent., is noxious to the seed. Tartaric acid, diluted to 2 per cent., is not unfavorable to the seed. Citric acid is unfavorable. Acetic acid is unfavorable when diluted with less than 400 times its volume of water. Tannic acid, diluted with 1,000 volumes of water, is favorable. Humic acid, diluted with 150 volumes of water, is favorable.

Carbonate of ammonia, when diluted with less than 300 volumes of water, is noxious to the germinating seed. Chlorid of potassium seems not to affect the embryo, but is favorable to the growing plant. Nitrate of potash diluted to less than $\frac{1}{500}$ is injurious. Bichromate of potassium in dilution of $\frac{1}{2000}$ destroys the germinating power of all seeds. Acetate of potassium diluted to less than $\frac{1}{500}$ has an injurious effect.

Nitrate of soda diluted to $\frac{1}{8}$ acts favorably upon the germinating seed. Sulfate of soda, diluted to a 11 per cent. solution, seems without positive action on seeds. Chlorid of soda in a 11 per cent. solution seems favorable to some species of seeds, but is unfavorable to the cereals and others.

Sulfate of lime (gypsum) acts favorably on seeds. Carbonate of lime seems in all cases to act favorably. Nitrate of lime, diluted to $\frac{1}{50}$, acts unfavorably upon seeds of crucifers.

Sulfate of magnesia, diluted to $\frac{1}{100}$, gives good results with oats. Sulfate of baryta also gives good results with oats.

The oils, ethers, alcohol, and solutions of alkaloids act unfavorably.

8.—THE SPECIFIC GRAVITY OF SEEDS.

The specific weight of seeds is their weight compared with that of an equal volume of water. The specific gravity of seeds varies with the stage of growth and with the amount of endosperm in the seed.

The specific gravity of the proximate constituents of seeds are as follows:

Starch	1.53	Fat	0.90–0.96	Ash, about	2.50
Sugar	1.60	Legumin	1.28–1.36	Water	1.00
Parenchyma	1.53	Protein	1.29	Air	0.0012

It is apparent from these figures that an increase in the mineral constituents of the seed will increase its specific gravity far more than an equal volume of organic matter.

Immature and withered seeds are of less specific gravity than mature seeds of the same kind, because in the former the cells remain empty or are filled with water and air.

The following table of specific gravity of well-ripened seeds is given by C. F. Renz in an inaugural dissertation at Tubingen, as quoted by Nobbe in *Handbuch der Samenkunde:*

Kind of Seed.	Specific Gravity.	Kind of Seed.	Specific Gravity.
Abies pectinata, Fir	0.833	Hordeum hexastichon, 6-rowed barley	1.350
Acer pseudo-plantanus, Maple	0.630	Hordeum vulgare, Common barley	1.351
Agrostemma githago, Cockle	1.233	Lactuca sativa, Lettuce	1.043
Agrostis Mexicana, Mexican Bent	1.100	Larix Europæa, Larch	0.848
Allium sibericum, Onion	1.184	Linum usatissimum, Flax	1.163
Amygdalus communis, Peach (pit)	1.033	Lithospermum officinale, Gromwell	1.223
Anchusa officinalis, Buglass	0.923	Medicago sativa, Lucerne	1.337
Aquilegia vulgaris, Columbine	1.220	Nicotiana rustica, Tobacco	1.095
Arrhenatherum avenaceum, Tall oat grass, with awn	0.600	Nicotiana tabaccum, Tobacco	1.046
Avena sativa, Oat	1.345	Panicum miliaceum, Common millet	1.179
Avena nuda, Tartarian oat	1.314	Papaver somniferum, Poppy	1.142
Beata vulgaris, Beet	0.536	Phaseolus communis, Bean	1.298
Betula alba, White birch	0.588	Phleum pratense, Timothy grass (cleaned)	1.022
Brassica campestris, Field cabbage	1.110	Pinus pinea, Stone pine	1.070
Brassica napus, Turnip	1.134	Pinus sylvestris, Scotch pine	0.807
Brassica præcox, Kohl rabi	1.143	Pisum sativum, Pea (large)	1.355
Bromus erectus, Upright brome	0.323	Pisum sativum, Pea (small)	1.324
Bromus inermis, Hungarian brome	0.746	Pyrus malus, Apple (seeds)	1.145
Canna Indica, Canna, Indian shot	1.365	Quercus robur, Oak (minus cup)	0.969
Cannabis sativa, Hemp	0.945	Ricinus communis, Castor bean	0.902
Carpinus betulus, Hornbeam	1.147	Rosa canina, Dog rose (seeds)	1.075
Chrysanthemum coronarium	0.770	Salvia officinalis, Sage	1.060
Cucumus sativa, Cucumber	1.041	Triticum vulgare, Wheat (sum'r)	1.337
Cucumus melo, Pumpkin	0.890	Triticum vulgare, Wheat (wint'r)	1.333
Datura stramonium, Jamestown weed	1.033	Triticum spelta, Spelt (cleaned)	1.347
Fagopyrum esculentum, Buckwheat	1.104	Triticum spelta, Spelt (in hull)	1.081
Holcus lanatus, Velvet grass	0.301	Vicia faba, Horsebean	1.298
Hordeum distichon, 2-rowed barley	1.317	Zea mays, Indian corn	1.147

The foregoing table shows that the highest specific gravity is found among the legumines, next rank the cereals, rich in starch. Free seeds generally have a low specific gravity. The oily seeds come next, and lightest of all are the seeds of composite plants. The limits within which the specific gravity of the same species may vary have been determined for wheat by O. Wolfenstein, who tested some thirty samples from different sources with the following results:

VARIATION OF VOLUME AND SPECIFIC GRAVITY IN WHEAT.

VARIETY.	SOURCE.	SHAPE.	COLOR.	Vol. of 100 seeds, in cubic centimeters.	Wt. of 100 seeds in grams	Specific gravity.
Wheat, White	Germany	Long-oval	Grayish yellow	2.306	3.107	1.400
Wheat, Summer	Germany	Round-oval	Brownish yellow	2.106	2.865	1.388
Wheat, English (?)	Germany	Longish	Brownish yellow	2.698	3.671	1.391
Wheat, Tuscan	Australia	Long-oval	Whitish yellow	3.984	5.650	1.415
Wheat, Purple Straw	Australia	Oval	Whitish yellow	4.725	6.671	1.397
Wheat, Siberian (?)	Australia	Long, like rye	Gray brown	1.567	2.159	1.414
Wheat, Michigan Amber	Michigan	Longish	Yellow brown	2.482	3.513	1.429
Wheat, Ohio Red	Ohio	Long-oval	Yellow brown	2.420	3.460	1.439
Wheat, Trit. Vulg. dur.	Tiflis	Long, 3-edged	Yellow brown	3.627	5.155	1.405
Wheat, Trit. Vulg. dur.	Hungary	Long, 3-edged	Yellow brown	2.209	3.086	1.427
Wheat, Mixed, average	Germany	Long-oval	White yellow	2.290	3.240	1.376
Wheat, Trit. Vulg. Turg.	Denmark	Roundish	White yellow	2.519	3.553	1.406
Wheat, Trit. Vulg. Turg.	Jutland	Oval	White yellow	2.744	3.853	1.397

9.—THE VOLUME WEIGHT OF SEEDS.

In the table of specific gravity, page 371, the specific gravity stands in no definite relationship with the volume, or "Dutch" weight. The volume weight is obtained by weighing in the air the contents of a standard measure, such as the bushel or the hectolitre. This weight is more or less influenced by the shape and size of the seeds which permit the seeds to form a more or less compact mass, and also by the shape of the vessel.

The volume weight of cereal seeds of the same harvest varies considerably: Wheat, from 100 to 155; oats, from 100 to 137; barley, 100 to 131; rye, 100 to 123. Small sized or withered seeds give a smaller volume weight than large plump seeds. The number of seeds in any measure increases with the volume weight and the weight of the individual seeds decreases in like ratio. With cereal seeds the absolute weight of the individual seeds invariably increases with the volume weight. Chemical analyses show that the higher the volume weight the better the edible quality of cereal or starchy seeds.

The following examples are given by A. Muller, quoted by Nobbe, *Handbuch der Samenkunde*, p. 322:

1.—WINTER RYE.	*Sample A.*	*Sample B.*
Specific gravity	1.39	1.39
Hectolitre weight	77.0	62.4 kg.
No. seeds per hectolitre	2,817,606	4,537,215
Average weight per seed	25.8	12.9 mg.
Volume of each seed	18.6	9.3 c. mm

2.—Winter Wheat.	*Sample A.*	*Sample B.*
Specific gravity	1.39	1.39
Hectolitre weight	86.9	55.9 kg.
No. seeds per hectolitre	2,403.583	3,993,903
Average weight per seed	30.2	13.2 mg.
Volume of each seed	23.1	9.5 c. mm

3.—White Oats.	*Sample A.*	*Sample B.*	*Sample. C.*
Specific gravity	- --	----	----
Hectolitre weight	62.6	54.2	45.7 kg.
No. seeds per hectolitre	1,944,016	1,744,822	1,547,073
Average weight of each seed	30.5	29.2	27.9 mg.

The foregoing examples show that the heavier the seeds, the greater the percentage of water and starch, and less of the other constituents, except in case of oats, in which the heavier seeds have a greater per cent. of protein.

In example 2—winter wheat—chemical analysis, according to A. Muller, shows that in purchasing one hectolitre each of the heavier (A) and lighter (B) samples, we would obtain the following quantities of the food-stuffs named:

	Sample A.			*Sample B.*	
Volume of weight	86.90 kilogram.			55.90	kilogram.
Water	13.60	kilogram	per hectolitre.	8.70	"
Crude fibre	2.21	"	"	3.38	"
Ash	1.37	"	"	1.01	"
Protein	10.28	"	"	7.25	"
Fat	2.27	"	"	1.33	"
Sugar	1.22	"	"	1.34	"
Starch	55 95	"	"	32.89	"
Total	86.90	"	"	55.90	"

The heavier seeds have a greater amount of endosperm, or food material, than the lighter, but it does not follow that the capacity to sprout, or the viability, is greater in heavier than in lighter seeds, or that the heavier seeds will produce the more vigorous plants. Prof. Nobbe gathered from a pine tree at successive periods from August 1 to November 1, 1,314 seeds of specific gravity less than 1, and 542 seeds of specific gravity greater than 1. Of the first class 70.3 per cent. germinated; of the second class only 1.3 per cent. germinated. For ordinary consumption, too, a sample of grain of lighter volume-weight may give better results than a heavier sample, as is shown in the case of spring wheat, which, although heavier than winter wheat, is worth less in the market. Winter barley has less volume weight than spring barley, but in breweries winter barley is preferred. Cereal seeds which have a very thick and hard coat, or testa, have a heavier volume-weight, but are of less value to the miller, brewer, and feeder, than thinner-skinned and lighter seeds. In many cases it is also easy to mix heavy fraudulent matter with seeds, thus increasing the volume-weight of sample. For these and other

reasons the volume-weight of seeds must be regarded as only one of several factors in determining the real value of seeds offered in the market. The more prudent way is therefore in all cases to purchase only after an actual test of sample, including determination of the purity and viability, as well as specific gravity and volume-weight.

10.—THE LIFE OF THE PLANT EMBRYOS.

During the development and life of the embryo in the seed we can distinguish three stages of progress, which may be designated respectively the (A) harvest stage, (B) the germinating stage, and (C) the inert stage.

A.—The Harvest Stage.

The first stage is characterized by the dissolution of the organic connection between the seed and the mother plant. The second stage is reached when the seed becomes capable of germinating under suitable environment. The third stage is reached when the viability of the embryo becomes extinct.

As soon as the fertilization of the ovule has been accomplished, the development of the embryo and the formation of endosperm in the embryo sack begins. The complete development of the embryo may take from a few days or weeks to years. With most agricultural plants the whole process is completed in from two to four weeks after fertilization of the ovule. The process of blooming, and consequently the ripening of the seeds, is longer continued in the centripetal than in the centrifugal floration. For example, rye, *secale cereale*, centrifugal inflorescence, ripens all of its seeds in from six to eight days after flowering; whereas, buckwheat, *Fagopyrum esculentum*, centripetal inflorescence, continues to ripen its seeds for some months.

As soon as the embryo, or "kernel," has developed its enveloping sack, and the food reserve, or endosperm, has been built up, the water contents of the seed rapidly decreases, and the seed becomes in consequence considerably crumpled and contorted, causing rupture of its organic connection with the mother plant. The seed is then "harvest ripe." It derives no more nourishment from the mother plant, and during its further connection the mother plant merely affords an asylum for the seed.

B.—The Germination Stage.—Seed Viability.

It is well known that even with many species of plants, when well ripened and normally developed seeds are planted, these may remain a long time in the seed-bed before germinating. Such seeds have small vital energy. Among the kinds of seed showing the extremes of vitality, we may name the clovers, the crucifers, and most cereals. In these seeds the harvest ripeness and germination ripeness are

scarcely distinguishable apart. Such seeds germinate well within twelve hours after the "harvest ripeness" stage occurs. On the other hand we find that most tree seeds require several months before the seed, under the most favorable surroundings, will germinate.

The common opinion that with the clover, cereals, flax and other seeds whose harvest-ripe and germination-ripe stages fall nearly or quite together are benefited by being kept for some time before again being sown is a mere prejudice not borne out by the facts as shown by careful tests. In many cases sound and viable seeds are delayed in sprouting by an impermeable seed coat, whereby the absorption of water and oxygen, and the consequent swelling of the seed, the first step in the germinating process, is prevented. This is well known in the case of seeds of the pulse tribe of forage plants and with many leguminous trees. Among the slowest seeds to sprout are sanfoin, serradella, and kidney vetch. Professor Nobbe took 300 seeds of sanfoin, removed the hulls from 100 and placed them in the germinating apparatus along with 100 seeds with hulls on, and 100 similar to the last he put between sheets of moist blotting paper. The following were the results:

	Days required for the given number of seeds to germinate.									Total. Per Cent.
	3	4	6	8	10	12	14	16	19	
100 unhulled seeds in apparatus	1	10	23	20	11	8	6	6	1	86
100 unhulled seeds in blotting paper	0	12	25	22	--	15	2	1	1	78
100 hulled seeds in apparatus	21	20	12	15	9	12	0	0	1	90

In practical seed-testing in the laboratory, as an average of many tests, the following is given as the time in which more than one-half the seeds used, may be expected to sprout:

The cereals, clovers, opium, poppy, crucifers, spurry, vetchlings, vetches, and peas, three days.

Cucurbits, beans, flax, spinach, buckwheat, and timothy grass, four days.

Oats, tall oat grass, canary grass, meadow fescue, and ray grasses, five days.

Red top, sanfoin, beet, carrot, and others, six days.

Meadow fox tail, yellow oat grass, sweet vernal, peas, Cynosurus, Dactylis and remainder of fescues, seven days.

When at the conclusion of a six day's germinating test of leguminous seeds, some seeds remain hard, it is certain that under ordinary favorable circumstances a portion of these will eventually germinate. After much experience in seed-testing, the German seed control stations have fixed upon one-third as the number of hard seeds of this family to be counted as viable after enduring unaltered a germinating trial of twelve or fourteen days. As regards other seeds, especially forest tree and flower seeds, a careful microscopic examination of

sections of the hard seeds must be made to determine whether or not the embryo is normally developed and sound, and of those in which the embryo appears normal and sound one-third, should be counted as viable in calculating the real worth of the sample.

The following table is compiled mainly from the records of the N. C. Experiment Station. Some of the figures are taken from foreign sources:

TABLE SHOWING NUMBER OF DAYS BEFORE ONE-HALF A SAMPLE MAY BE EXPECTED TO SPROUT.

SCIENTIFIC NAME.	COMMON NAME.	No. of days before first germination	No. of days before one-half sample germinated.
GRAMINEÆ:			
Zea mays	Indian corn	3	4— 5
Alopecurus pratensis	Meadow foxtail	4—5	7— 8
Phleum pratense	Timothy	2—3	4
Phalaris canariensis	Canary grass	1—2	5— 6
Holcus lanatus	Soft velvet grass	4—5	6— 7
Anthoxantum odoratum	Sweet vernal grass	5—6	7— 9
Agrostis stolonifera	Fiorin	4—6	6— 8
Avena sativa	Oats	1—2	5— 6
Arrhenatherum avenaceum	Tall meadow oat grass	3—4	5— 6
Poa pratensis	Kentucky blue grass	5—6	7— 8
Poa trivialis	Rough stalked mead. grass	5—6	7— 8
Cynosurus cristatus	Crested dog's tail grass	5—6	7— 8
Dactylis glomerata	Orchard grass	5—6	7— 8
Festuca ovina	Sheep's fescue	4—5	7— 8
Festuca pratensis	Meadow fescue	3—4	5— 6
Festuca rubra	Red fescue	4—5	7— 8
Pennesetum spicatum	Pearl millet	3—4	4— 6
Lolium perenne	English ray grass	3	5— 5
Lolium Italicum	Italian ray grass	3	5— 6
Sorghum sp.	Sorghums	2	4— 8
Triticum vulgare	Wheat	1—2	3— 4
Secale cereale	Rye	1—2	3— 4
Hordeum vulgare	Barley	1—2	3— 4
LILIACEÆ:			
Allium cepa	Onion	2—3	5— 6
CONIFERÆ:			
Picea vulgaris	Silver fir	3—5	7— 9
Pinus sylvestris	Scotch pine	4—5	7— 9
Pinus austriaca	Black pine	4—5	7— 9
Abies pectinata	Fir	9—10	15—20
Larix Europæa	Larch	5—6	10—13
CHENOPODIACEÆ:			
Spinacia oleracea	Spinach	1—2	4— 5
Beta vulgaris	Beet	3—4	6— 7
POLYGONACEÆ:			
Fagopyrum esculentum	Buckwheat	2—3	4— 5
Rumex patientia	Patience dock	2—3	4— 5
PLANTAGINEÆ:			
Plantago lanceolata	English plantain	½—1	3— 4
COMPOSITÆ:			
Chicorium indiva	Endive	1—2	3— 4
Helianthus annuus	Sunflower, mammoth	2—3	5— 7
Achillea milfolium	Yarrow	2—3	4— 8
Lactuca sativa	Lettuce	1—2	3— 4

TABLE SHOWING NUMBER OF DAYS, ETC.—*Continued.*

SCIENTIFIC NAME.	COMMON NAME.	No. of days before first sprout.	No. of days before one-half sample sprouted.
SOLANACEÆ:			
Lycopersicum esculentum	Tomato	3—4	6— 8
Solanum melongena	Egg plant	4—5	9—10
Capsicum annum	Pepper	3—7	10—12
UMBELLIFERA:			
Apium graveoleus	Celery	6—7	10—12
Petroselinum sativum	Parsley	3—6	9—11
Pastinaca sativa	Parsnip	....	.....
Daucus carota	Carrot	3—4	6— 7
PAPAVERACEÆ:			
Papaver somniferum	Opium poppy	1—2	3— 4
Papaver rhœas	Garden poppy	1—2	2— 4
CRUCIFERÆ:			
Lepidium sativum	Cress	½—1	2— 3
Brassica, sp.	Cab'ge, turnip, must'd, etc.	½—1	2— 3
Raphanus sativa	Radish	½—1	2— 3
CUCURBITACEÆ:			
Cucurbita pepo	Pumpkin	2—3	4— 5
Cucumis sativus	Cucumber	2—3	4— 5
Cucumis melo	Muskmelon	2—3	4— 5
Citrullus vulgaris	Watermelon	2—3	4— 6
CARYOPHYLLACEÆ:			
Spergula arvense	Spurry	2	3— 4
LINACEÆ:			
Linum usitatisimum	Flax	1—2	4— 5
PAPILIONACEÆ:			
Anthyllis vulneraria	Kidney vetch	1	2— 3
Medicago sativa	Lucerne	½—1	2— 3
Medicago media	Sand lucerne	½—1	2— 3
Medicago lupulina	Hop-trefoil	½—1	2— 3
Medicago maculata	Spotted medic	½—1	2— 3
Melilotus leucantha	Bokhara clover	1—2	3— 4
Trifolium pratense	Red clover	½—1	2— 3
Trifolium repens	White clover	½—1	2— 3
Trifolium hybridum	Alsike clover	½—1	2— 3
Trifolium incarnatum	Crimson clover	2—3	.....
Lotus corniculatus	Birdsfoot trefoil	2—3	5— 6
Lathyrus sativus	Vetchling	2—3	2— 3
Lathyrus odoratus	Flat pea	2—3	3
Vicia sativus	Vetch	2—4	3
Vicia faba	Horsebean	2—3	.....
Glycine hispida	Soy, or soja pea	2—3	4— 5
Pisum sativum	Garden pea	1—2	3— 4
Phaseolus vulgaris	Bean	1—2	3— 4
Phaseolus radiatus	Japan red bean	2—3	4— 5
Dolichos sinensis	Cowpea	1—2	3— 4
Ervum lens	Lentil	2—3	4— 5
Ornithopus sativus	Serradella	3—4	5— 6
Onobrychis sativa	Sanfoin	3—4	6— 7
Lupinus luteus	Yellow lupin	2	4— 5

C.—The Inert Stage.

The length of time during which a normally developed seed will under ordinary circumstances retain its viability, is a matter of the very greatest importance to all who handle or use seeds. No definite rule for general application can be laid down. There is a popular prejudice in favor of recently harvested seeds. As everybody wants "fresh seeds" the seedsmen are often tempted to handle immature and undeveloped seeds which, while in truth "fresh," are nevertheless of very feeble viability or wholly inert.

Long experience from results at this and foreign stations in seed testing, has furnished the following data as to the number of years during which normally developed and well ripened seeds of the sorts named will, under ordinary favorable conditions, retain their viability: Wheat, 3 years; other cereals, millet and most grasses and clovers, 2 years; cabbage, turnip, rape, 3 years; mustard, hemp and flax, 4 years. The viability of most forest tree seeds is extremely fugacious. With the seeds of the majority of the more common forest trees, under ordinary circumstances, the embryo retains its vitality no longer than the spring succeeding the year they were ripened. The oak, beech, maple and fir are such trees. Still shorter is the life of seeds of the poplar, willow and elm. These latter seeds must be sown or bedded as soon as ripe, as they become inert in a few days. The life of pine and spruce seeds has a three years' duration, and the larch three or four years.

Although seed vitality is in general so feeble there is no good reason why seeds, fully developed and preserved under the most favorable circumstances, should not remain dormant and viable for an indefinite period or for more than a century. The so-called Talevera wheat is reported on respectable authority to have been derived from a seed found in an Egyptian tomb. Seeds of *Centaurea cyanus*, *Heliotropium vulgare* and *Trifolium minimum*, found in a sealed casket in an old tomb at Mountjoy, St. Denis, in France, have reproduced the above named plants. This tomb dated back to the third or fourth century of the Christian era, and the genuineness of the find has never been disproved.

Charles Moulins (*Comtes Rendu Soc. Linn. de Bordeaux*, VII., 1835) reports having, during some archeological researches, found at a depth of eight feet, among articles dating back to the period before the conquest of Gaul by the Romans, seeds which sprouted and reproduced the plant *Mercurialis annua*. Many botanists have germinated seeds taken from herbarium specimens labelled for several decennials, and in at least one case from a specimen of *Echium vulgare*, known to be 300 years old.

These indisputable evidences of longevity of dormant seeds gives us cause to hope that when the various factors concerned in developing the seed embryo and conserving its viability are better known, the term "old seeds" will have lost its terrors.

In practical agriculture it is necessary to recognize the fact that the seeds of the market are very apt to lose the capacity to germinate after a period, varying for different genera of plants, but comparatively short for all.

The greatest difficulty in the way of determining the duration of the life of the seed embryo, under ordinary commercial usage, is to obtain old seeds of known age and a sufficiently great age to give the maximum limits.

The following table is given in Nobbe's *Handbuch*. The succeeding table is reprinted from Bulletin 67*a* of the N. C. Experiment Station. These series of tests are much too short to be wholly trustworthy, but may be taken so far as they go as approximately correct:

TABLE SHOWING VIABILITY OF SEEDS KNOWN TO BE AT LEAST TEN YEARS OLD.

FAMILY.	GENERA.	COMMON NAME.	Per Cent. of Viable Seeds.	REMARKS.
Gramineæ	Zea mays	Indian corn	10	Two samples; 3 samples gave 0.
Gramineæ	Triticum vulgare	Wheat (Kensingt'n)	10	Several other varieties gave 0.
Gramineæ	Sorghum vulgare	Sugar cane	0	Samples from Japan Austria and Egypt.
Gramineæ	Panicum echinatum	Spring panic grass	3	Other panicums gave 0.
Urticaceæ	Cannabis sativa	Hemp	0	
Compositeæ	Chicorium intybus	Chicory	35	From Egypt.
Caryophyllaceæ	Spergula arvense	Spurry	41	Eleven years old.
Solonaceæ	Lycopersicum esculentum	Tomato	20	
Cruciferæ	Sinapsis Pekinensis	Chinese mustard	5	
Cruciferæ	Brassica napus	Turnip	0	
Cruciferæ	Brassica campestris, var.	Rape	30	
Cruciferæ	Brassica campestris, var.	Russian kubja rape	40	
Cruciferæ	Brassica campestris, var.	Rutabaga	27	
Malvaceæ	Abutilion avicennæ	Cottonweed	15	
Linaceæ	Linum usitatissimum	Flax	14	Sample from Egypt; another sam. gave 0.
Leguminеæ	Trifolium hybridum	Alsike clover	1	Two per cent. of sample remained hard.
Leguminеæ	Medicago media	Sand lucerne	12	
Leguminеæ	Various genera	Bokhara and crimson clover, sanfoin, serradella, horseb'n	0	
Leguminеæ	Vicia sativa	Brown vetch	14	Several other samples [gave 0.
Leguminеæ	Pisum sativum	Garden pea	24 30 55	Three samples; several gave 0.
Leguminеæ	Dolichos, several species	Closely related to the cowpea.	0	
Leguminеæ	Lupinus termis	Roman lupine	0	
Leguminеæ	Phaseolus vulgaris	Comm'n bush bean	0	Several samples.
Leguminеæ	Phaseolus sativus		75	One other sample gave 0.

TABLE SHOWING VIABILITY OF SEEDS KNOWN TO BE SIX OR SEVEN YEARS OLD.

COMMON NAME.	Per Cent. of Viable Seeds.
Sunflower, small Russian	0.
Sunflower, large Russian	21.
Gourd, Southern	20.
Pea, garden	0.
Pea, garden	7.
Bean, large lima	0.
Bean, marrowfat	0.
Sanfoin	0.
Millet, golden	1.
Millet, Hungarian	0.
Clover, mammoth	1.
Timothy grass	0.
Randall grass	2.
Rye grass, Italian	1.
Meadow foxtail	0.
Johnson grass	1.
Castor oil bean	5.
Oats, rust proof	83.
Oats, black	71.
Buckwheat, silverhull	0.
Rice	13.
Barley	14.
Cotton	0.
Wheat, flint	0.
Wheat, Fultz	0.
Wheat, Caldwell's rust proof	0.

These tables show that for the longest-lived seeds, under ordinary mercantile practice, 10 years is about the maximum limit, while for the large majority of such seeds the limit is below six years.

To learn how rapidly the devitalizing process progresses, Prof. Nobbe made annual tests from the same packages of various seeds from 1870 to 1874, with the following results:

Flax, average of 13 samples, 1870—72.3 per cent.; 1872—54.3 per cent.; 1873—46.9 per cent.; 1874—38.5 per cent.

Spurry, average of 7 samples, 1871—89 per cent.; 1874—85 per cent.

Red clover, average of 32 samples, 1870—87 per cent.; 1872—70 per cent.; 1873—53 per cent.; 1874—43 per cent.

Pea, average of 21 sampls, 1871—96 per cent.; 1873—88 per cent.

Turnip, average of 6 samples, 1870—77 per cent.; 1872—59 per cent.

Mustard, average of 2 samples, 1870—86 per cent.; 1872—76 per cent.

Rye, 1 sample, 1870—100 per cent.; 1872—87 per cent.; 1875—26 per cent.

Timothy grass, average of 23 samples, 1870—83 per cent.; 1872—67 per cent.; 1873—53 per cent.; 1875—46 per cent.

Soft velvet grass, average of 5 samples, 1871—39 per cent.; 1874—22 per cent.

Fiorin grass, average of 4 samples, 1871—21 per cent.; 1874—20 per cent.

Meadow fescue grass, 1 sample, 1871—26 per cent.; 1874—9 per cent.

Sheep's fescue, average of 3 samples, 1871—21 per cent.; 1874—7 per cent.

Red fescue, average of 8 samples, 1871—23 per cent.; 1874—6 per cent.

Austrian pine, average of 8 samples, 1871—60 per cent.; 1874—30 per cent.

The above table shows that the decrease of viability is not generally so rapid as has been supposed. But many of the seeds which germi-

nated under the wholly favorable conditions arranged by Nobbe would have failed to sprout in the field, or would have produced feeble and worthless plants.

In testing old seeds, along with the constantly decreasing viability percentage, we find also an obvious qualitative deterioration. Old seeds are always characterized, according to their age, by loss of their original color and lustre. Such seeds, too, even when the cotyledous or shoot axis emerges from the seed in the sprouting pan are apt to have a malformed root axis or none at all, rendering them practically unviable. Seeds rich in oil and protein appear to deteriorate more rapidly than starchy seeds. Of course in considering the progressive deterioration shown in the foregoing tables, it must be remembered that in the beginning, as the sample tested was small and each year grew smaller, the figures for different years are not exactly comparable.

III. PRACTICAL SEED TESTING.

1.—VIABILITY, PURITY, AND GERMINATION OF SEEDS.

For the economical purchase of seeds, there are four fundamental points to be considered, viz.:

1.—Whether the seeds are the species desired.

2.—Whether they are of at least average volume-weight.

3.—Whether the sample is free from deliberate adulteration and from noxious impurities.

4.—Whether the sample possesses a high percentage of viable seeds and high vital energy, as shown by the rapidity with which germination takes place.

In purchasing seeds in the market we cannot expect to obtain the highest possible quality or 100 per cent. of "real worth"; 100 per cent. is the ideal standard of measurement and at best we can only hope to approximate it. Agricultural seeds giving 95 per cent. "real worth" may be considered of very high grade, because from necessity these seeds are grown, cured and handled in a wholesale way by machinery, and are always more or less mixed with dirt, trash and foreign seeds.

The percentages of purity and viability that may be reasonably looked for in good marketable seeds are given in the table on page 383, *et seq.* These figures are made up by combining the average results obtained in testing seeds during a series of years in this country and Europe. The viability percentage is that possible under artificially favorable circumstances, as in ordinary laboratory seed testing, where the degree of temperature, moisture, etc., are fully under control and are varied to suit different classes of seeds. The viability percentage found in laboratory testing is always higher than in ordinary field practice, because in field practice the amount of moisture, heat, light and oxygen are either not at all or only in a small degree under control.

To estimate the *Real* or *Agricultural Worth* of a seed sample, we must combine the purity and viability percentages, thus:

$$\frac{\text{Viability} \times \text{Purity}}{100} = \text{Real or Cultural Worth in terms of per cent.}$$

We must also consider the nature of the foreign constituents of the sample. If we have a sample of Red clover in hand, it is a very important matter, from a practical standpoint, to know whether the impurities present are timothy and other useful seeds, or seeds of dodder, plantain, wild carrot, and other noxious weeds.

The table following gives, in a condensed form, the average percentages of purity and viability that extensive series of microscopic

examinations and germinating tests have shown choice seeds to possess. The last three columns give the maximum, minimum, and optimum temperatures for germinating these seeds. The data for this table has been collated from the records of the North Carolina Experiment Station, and several other American stations, as well as from very complete reports received from the French National Station in Paris, the Swiss Station at Zurich, the Kiel Station in Germany, and the Danish Station in Copenhagen. The late Peter Henderson furnished from his own experience a very full set of figures as to purity and viability, and many other American and foreign seedsmen have furnished valuable data which has been incorporated into this table. This table does not assume to give the figures for the highest possible grade of seeds, but only for choice merchantable seed. Seed falling more than 5 per cent. in cultural value below these figures cannot be called choice. The real or cultural worth of the different species is found in terms of per cent., by multiplying the purity by the viability and dividing by 100, as shown on the preceding page.

TABLE SHOWING VIABILITY AND PURITY OF GOOD COMMERCIAL SEEDS, AND TEMPERATURE AT WHICH THEY GERMINATE.

KIND OF SEED.	VIABILITY, PER CENT.	PURITY, PER CENT.	GERMINATING TEMPERATURE.		
			Max. °F.	Min. °F.	Opt. °F.
GRASSES AND CEREALS:					
Agrostis stolonifera (fiorin)	82.0	71.1	95	60	75
Agrostis vulgaris (red top)	72.0	97.4	95	60	75
Alopecurus pratensis (meadow foxtail)	42 0	83.5	95	60	75
Authoxantum odoratum (sweet vernal)	30.0	85 7	95	60	75
Authoxantum puelli (annual sweet vernal)	26.0	83.7	95	60	75
Arrhenatherum avenaceum (tall oat grass),	69.0	68.1	95	60	75
Avena sativa (com. oat)	95.0	97.5	90	55	70
Avena flavescens (yellow oat grass)	37.0	42.5	95	60	75
Bromus mollis (soft chess)	46.0	64.4	90	55	70
Bromus inernis (Hungarian brome)	81.0	76.3	90	55	70
Bromus pratensis (meadow brome)	61.0	77.4	90	55	70
Bromus schraderi (rescue grass)	70.0	95.0	90	55	70
Cynodon dactylon (Bermuda grass)	52.0	98.5	95	65	80
Cynosurus cristatus (crested dogstail)	62.0	89.1	95	60	75
Dactylis glomerata (orchard grass)	81.0	73.9	95	60	75
Festuca duriuscula (hard fescue)	67.0	86.7	95	60	75
Festuca elatior (Randall grass)	83.0	85.4	95	60	75
Festuca tenuifolia	60.0	71.4	95	60	75
Pestuca ovina (sheep's fescue)	71.0	80.3	95	60	75
Festuca pratense (meadow fescue)	81.0	86.9	95	60	75
Festuca rubra (red fescue)	48.0	73.1	95	60	75
Holcus lanatus (velvet grass)	39.0	68.2	95	60	75
Hordeum vulgare (cult. barley)	82.0	97.9	95	50	65
Lolium Italicum (Italian rye grass)	73.0	93.0	95	50	75
Lolium perenne (English rye grass)	76.0	94.3	95	50	75
Oryza sativa (cult. rice)	85.0	97.1	95	65	80
Panicum germanicum (golden millet)	88.0	97.5	95	65	80
Panicum miliaceum (millet)	82.0	98.0	95	65	80
Panicum sanguinale (crab grass)	85.0	97.5	95	65	80
Penicillaria spicata (pearl millet)	82.0	98.0	95	65	80

TABLE SHOWING VIABILITY AND PURITY OF GOOD COMMERCIAL SEEDS—*Continued.*

KIND OF SEED.	VIABILITY, PER CENT.	PURITY, PER CENT.	GERMINATING TEMPERATURE.		
			Max. °F.	Min. °F.	Opt. °F.
GRASSES AND CEREALS—*Contiuued:*					
Phleum pratense (timothy)	89.0	97.6	95	60	75
Poa arachnifera (Texas blue grass)	60.0	88.5	95	60	75
Poa compressa (June grass)	70.0	80.8	95	60	75
Poa nemoralis (wood grass)	60.0	78 9	95	60	75
Poa pratense (Kentucky blue grass)	60 0	84.8	95	60	75
Poa serotina (fowl meadow grass)	75.0	83.5	95	60	75
Poa trivialis (rough stalked meadow grass)	55.0	85.0	95	60	75
Secale cereale (cult. rye)	91.0	99.0	90	55	75
Setaria Italica (Italian millet)	87.0	97.5	95	60	75
Sorghum halapense (Johnson grass)	75.0	95.0	99	65	80
Sorghum nigrum (sugar cane)	75.0	97.5	99	65	80
Sorghum saccharatum (broom corn)	75.0	97.5	95	60	75
Triticum vulgare (cult. wheat)	95.0	98.2	95	55	75
Zea mays (Indian corn)	95.0	98.5	100	65	85
FORAGE LEGUMINES:					
Hedysarum coronarium (sulla)	85.0	95.0	100	65	85
Lespedeza striata (Japan clover)	76.0	98.0	100	65	80
Melilotus alba (Bokhara clover)	87.0	97.0	100	65	80
Medicago lupulina (yel'w trefoil, nonesuch)	77.0	95.3	100	65	80
Medicago maculata (spot. medic, burr clov.)	90.0	95.0	100	65	80
Medicago media (sand lucerne)	80.0	96.2	100	65	80
Medicago sativa (lucerne)	88.0	97.5	100	65	80
Onobrychis sativa (sanfoin)	85.0	96.9	100	65	80
Ornithopus sativus (serradella)	95.0	96.7	100	65	80
Spergula arvense (spurry)	78.0	98.1	100	65	80
Dolichos sinensis (cowpea)	95.0	98.5	110	65	85
Trifolium hybridum (alsike clover)	73.0	95.4	95	60	75
Trifolium incarnatum (crimson clover)	89.0	97.3	100	65	80
Trifolium pratense (red clover)	91.0	96.7	95	60	80
Trifolium pratense, var-perenne (mammoth, or pea-vine clover)	93.0	96.7	95	60	80
Trifolium repens (white clover)	86.0	94.5	95	60	80
FIELD AND GARDEN CROPS:					
Asparagus	80.0	98.5	90	60	75
Beans, bush	90.0	99.5	90	60	75
Beans, lima	95.0	99.5	100	65	80
Beets	133.0	97.5	90	60	75
Broccoli	65.0	99.0	90	55	70
Brussels sprouts	89.0	99.0	90	55	70
Buckwheat, mammoth	92.0	98.8	90	55	70
Buckwheat, silverhull	82.0	98.8	90	55	70
Cabbage	89.0	99.0	90	55	70
Cauliflower	80.0	99.5	90	55	70
Carrot	59.0	90.5	90	55	70
Celery	32.0	99.0	90	55	70
Chicory	72.0	98.0	90	55	70
Cotton, upland	82.0	97.0	100	65	80
Cotton, sea island	80.0	97.0	100	65	80
Cucumber	86.0	99.0	100	65	80
Egg plant	60.0	99.0	100	65	80
Endive	94.0	97.0	90	55	70
Kale	95.0	98.5	90	55	70
Kohl rabi	88.0	98.5	90	55	70
Leek	55.0	98.5	90	55	70
Lettuce	77.0	98.0	90	55	70

TABLE SHOWING VIABILITY AND PURITY OF GOOD COMMERCIAL SEEDS—*Continued.*

KIND OF SEED.	VIABILITY, PER CENT.	PURITY, PER CENT.	GERMINATING TEMPERATURE.		
			Max. °F.	Min. °F.	Opt. °F.
FIELD AND GARDEN CROPS—*Continued:*					
Lupine, yellow	79.0	98.5	95	60	75
Melon, musk	90.0	99.0	100	65	80
Melon, water	89.0	99.0	100	65	80
Mustard	95.0	98.0	90	55	70
Okra	85.0	99.0	100	65	80
Onion	85.0	99.0	80	50	65
Parsnip	75.0	99.0	90	55	70
Parsley	70.0	98.5	90	55	70
Peanut	95.0	98.5	98	60	75
Pea, garden	97.0	99.0	80	50	65
Pepper	76.0	98.0	100	65	85
Pumpkin	85.0	98.5	100	65	85
Rhubarb	85.0	96.5	90	55	70
Radish	95.0	99 0	90	50	70
Sage	55.0	96.0	90	50	70
Salsify	83.0	98.0	90	50	70
Scorzonera	86.0	98.0	90	50	70
Spinach	89.0	98.0	90	50	70
Squash	90.0	99.0	100	65	85
Sunflower	85.0	99.0	100	65	85
Tobacco	88.0	99.0	90	60	70
Tomato	80.0	98.0	100	65	80
Turnip	94.0	99.0	100	65	80
Thyme	60.0	97.0	100	65	80
FLOWER SEEDS:					
Aquilegia	53.0	99.5	90	60	70
Canterbury bell	75.0	99.5	90	60	70
Carnation	68.0	99.5	90	30	70
Catchfly	85.0	99.5	90	60	70
Centaurea	68.0	99.5	90	60	70
Chrysanthemum, annual	65.0	99.5	90	60	70
Cineraria	60.0	99.5	90	60	70
Clarkia	70.0	99.5	90	60	70
Cobea	60.0	99.5	95	65	80
Clematis	50.0	99.5	90	60	70
Convolvulus	93.0	99.5	90	60	70
Coleus	68.0	99.5	95	65	80
Datura	78.0	99.5	95	65	80
Dahlia	70.0	99.5	95	65	80
Daisy, bellis	70.0	99.5	90	60	70
Digitalis	85.0	99.5	90	60	70
Dianthus	79.0	99.5	90	60	70
Dolichos, hyacinth bean	89.0	99.5	95	65	80
Evening primrose	70.0	99.5	95	65	80
Eschscholtzia	90.0	99.5	95	65	80
Gaillardia	80.0	99.5	90	60	70
Heliotrope	70.0	99.5	95	65	80
Hibiscus	70.0	99.5	95	65	80
Hollyhock	75.0	99.5	95	65	80
Larkspur	60.0	99.5	95	65	80
Lobelia	80.0	99.5	95	65	80
Lychnis	70.0	99.5	95	65	80
Marigold	89.0	99.5	95	65	80
Maurandya	70.0	99.5	95	65	80
Mimulus	75.0	99.5	95	65	80

TABLE SHOWING VIABILITY AND PURITY OF GOOD COMMERCIAL SEEDS—*Continued.*

KIND OF SEED.	VIABILITY, PER CENT.	PURITY, PER CENT.	GERMINATING TEMPERATURE.		
			Max. °F.	Min. °F.	Opt. °F.
FLOWER SEEDS—*Continued:*					
Pansy	66 0	99.5	95	65	80
Pyrethrum	69 0	99.5	95	65	80
Mignonette	70.0	99.5	95	65	80
Nemophila	84.0	99.5	95	65	80
Nigelia	65.0	99.5	95	65	80
Nasturtium	90.0	99.5	95	65	80
Portulaca	93.0	99 5	90	60	70
Poppy, garden	90.0	99.5	90	55	65
Phlox	63.0	99.5	90	55	65
Petunia	80.0	99.5	90	60	70
Primula (sinensis fimb.)	60.0	99.5	90	60	70
Ricinus	80 0	99 5	95	65	80
Salvia	70 0	99.5	90	60	70
Scabiosa	85.0	99.5	90	60	70
Stock	75.0	99.5	90	60	70
Sweet pea	75.0	99.5	80	50	65
Sweet William	70.0	99.5	90	60	70
Verbena	70 0	99.5	90	60	70
Vinca	70.0	99.5	95	65	80
Violet	68.0	99.5	90	60	70
Zinnia	90.0	99.5	95	65	80

2.—SEEDS, THEIR IMPURITIES AND ADULTERATION.

THE GRASS FAMILY.

Fig. 4. VELVET GRASS. *a.* and *b.* spikelet; *c.* caryopsis and sterile flower obive; *a.* natural size.

Bermuda grass seed is all imported. It is generally very clean, as this grass does not permit other plants to grow with it.

Crested dog's-tail grass seed is nearly all imported from Europe, and generally contains more or less seeds of velvet grass (*Holcus lanatus*), shown at Fig. 4, and blue pearl grass (*Molina caerula*), shown at Fig. 5. Both of these are worthless weeds, and the latter grass is dangerous to the health of stock which eat it. Sheep's fescue seeds are also used to adulterate samples of crested dog's-tail.

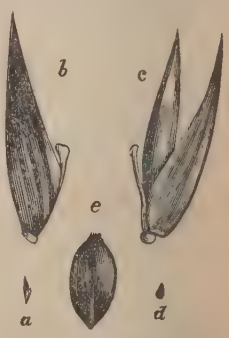

Fig. 5. BLUE PEARL GRASS. *a. b. c.* spikelet; *d. e.* caryopsis; *a.* and *d.* natural size.

Tall fescue seed is frequently adulterated with seeds of English rye grass, a useful but much cheaper seed. To the uncritical eye these two kinds of seeds are very difficult to distinguish. Fig. 6 shows seeds of tall fescue; Fig. 7 seeds

of English rye grass. It will be observed that the stalk at the base of the fescue seed is long, slender, and the top is nearly circular in outline. In the case of the rye grass the stalk is short and thick, and decreases in diameter from the top to the bottom, and the top is nearly oval in outline. The other fescue grasses are not generally adulterated, but sheep's fescue (*F. ovina*) is frequently sold under the name of red fescue. It is quite impossible for anyone but an experienced botanist to distinguish the seeds of the true red fescue from those of sheep's fescue. The dealer should be required to specially guarantee the genuineness of his red fescue seed, to be determined best by analyzing a specimen of the grass produced by the seed.

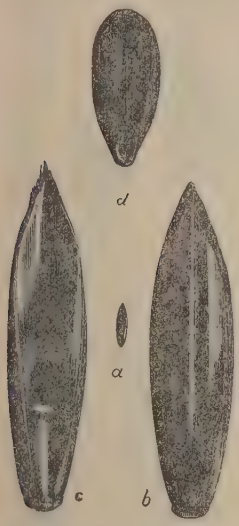

Fig. 6. MEADOW FESCUE GRASS.
a. flower, natural size; *b*, *c*. same magnified—front and back views; *d*. naked caryopsis.

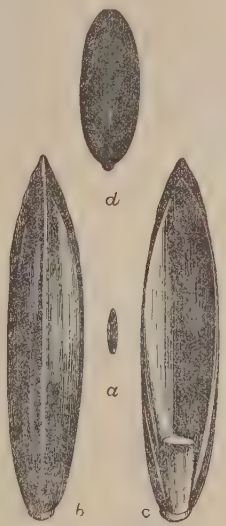

Fig. 7. ENGLISH RYE GRASS.
a. flower, natural size; *b*. and *c*. same magnified; *d*. caryopsis.

Fowl meadow grass seed is often mixed with seeds of buttercup (*Ranunculus bulbosus* and *repens*, Fig. 8), and with seeds of various aquatic weeds. Seeds of rough-stalked meadow and red-top grasses are also usually present, but these are good seed and do not injure the quality of the sample.

Johnson grass seed, as sold, is not usually mixed with any other, but uncleaned seed is often very foul with chaff and straw.

Kentucky blue grass is not, as a rule, adulterated, and seldom contains other grass seeds as impurities. The one most often found is tufted hair-grass (*Aira caespitosa* and *A. flexuosa*, Fig. 9). "Uncleaned" blue grass seed usually contains from 20 to 30 per cent. of its weight in chaff and the woolly hairs found attached to the base of the seed. The "extra-cleaned" grade of this seed should be always purchased. It is the cheapest.

Meadow fox-tail grass seed comes chiefly from Europe. Samples are very frequently adulterated with seeds of velvet grass (Fig. 4), which bear some resemblance to the true fox-tail seed. A compari-

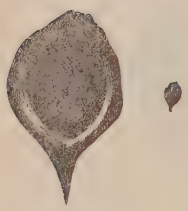

Fig. 8. BUTTERCUP.

Fig. 9. HAIR GRASS.
a. c. d. flower, back and side views; *e.* and *f.* caryopsis; *a.* and *e.* natural size.

Fig. 10. RESCUE GRASS.
a. natural size. *Rescue grass*, *Bromus unioloides*, is sometimes found as an impurity in oats, and *vice versa*.

son of Fig. 4 with Fig. 11, true meadow fox-tail seed, will show the different appearance of the two kinds of seed. It will be observed

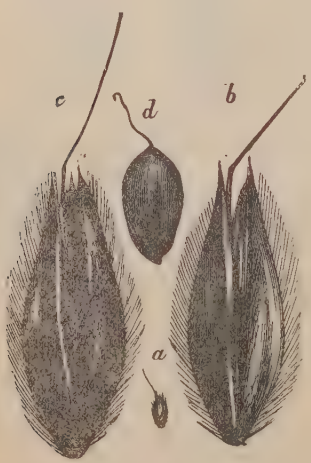

Fig. 11. MEADOW FOX-TAIL GRASS.
a. b. c. spikelet; *d.* caryopsis; *a.* natural size.

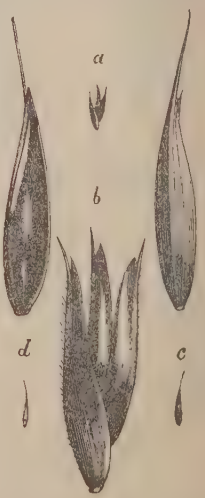

Fig. 12. ORCHARD GRASS.
a. natural size; *a. b.* spikelet; *c. d.* flowers.

that the exterior glumes or husks of velvet grass have short, thick and hooked awns, whereas true fox-tail seed has only one awn, which

is long and slender and bent in the middle. The seeds of creeping fox-tail grass (*Alopecurus agrestis*) are not infrequently substituted for meadow fox-tail. These are harder to detect. The edges of meadow fox-tail seeds have abundant and rather long soft hairs. Those of creeping fox-tail have only a few short and stiff hairs. The seeds of true fox-tail are softer, whiter and flatter than those of the creeping species.

Orchard grass seed is not commonly adulterated, but when sold in the uncleaned state the sample often contains one-fifth of its weight in chaff, dirt, and various weed seeds. The most common of these

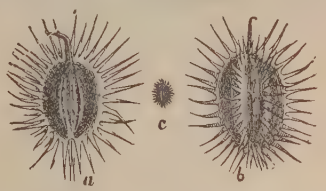

Fig. 14. Wild Carrot.
c, natural size; *a*, *b*, front and edge views.

Fig. 13. Italian Rye Grass.
a, natural size; *a*, *b*, *c*, flower—front and back views; *d*, caryopsis.

Fig. 15. Chess.
a, spikelet; *b*, *c*, flower—front and back view; *a*, *b*, *c*, natural size.

weed seeds are ox-eye daisy (*Chrysanthemum leucanthemum*), carrot (*Daucus carota*), dog fennel (*Maruta cotula*) and knot weeds (*Polygonum*). When deliberately adulterated, the seeds most commonly employed for this purpose are those of sheep's fescue. Seed imported from Europe is apt to contain also seed of blue pearl grass (Fig. 5) and seeds of several species of brome grass (Fig. 15).

English rye grass seed is not usually adulterated, as it is itself one of the cheapest seeds in the market. The samples come chiefly from England and Scotland, where rye grass is the prevailing herbage of wet meadows. Badly cleaned samples are apt to contain a good deal of velvet grass (Fig. 4) and soft brome grass (*Bromus mollis*), plantain (*Plantago lanceolata*), and buttercup (*Ranunculus*, Fig. 8).

Italian rye grass seed is not infrequently adulterated with seed of English rye grass, which is a cheaper seed. Fig. 7 shows English rye grass seed. Fig. 13 shows Italian rye grass seed. The latter is awned; the former is not. The stalk at the base of Italian rye grass seed is more slender than that at the base of English rye grass seed.

Red-top seed is not usually adulterated. Uncleaned samples are apt to contain seeds of timothy, fowl meadow and other moist land grasses, as well as seeds of sedges, buttercup (Fig. 8) and divers bog weeds.

Rough-stalked meadow grass is not extensively sold in the market in this country. The seed used is chiefly imported from Europe, where

Fig. 16. YELLOW OAT GRASS.
c. natural size; *a. b. c.* flowers.

Fig. 17. TALL OAT GRASS.
a. b. spikelet; *c. d.* caryopsis; *a.* natural size.

this species is esteemed above its sister species, our Kentucky blue grass. The latter species is therefore apt to be used to adulterate samples of the former, and they are rather difficult to distinguish. The seeds of rough meadow grass (*Poa trivialis*) have a bluish tinge, are more slender than those of Kentucky blue grass, and have fewer woolly hairs at the base and on the back. Other and worthless species of annual *Poas* are also used to debase samples of rough meadow grass seed. Blue pearl grass (Fig. 5) is used for the same purpose.

Sweet vernal grass seed is nearly all imported from Europe. This seed is one of the most expensive handled by the trade, and the temptation to adulterate is consequently great. The annual variety (*Anthoxantum puelli*) is not infrequently substituted altogether for the true

perennial species. These two kinds of seeds are very difficult to distinguish. The annual seeds are lighter colored, and the husks are shorter than is the case with the true perennial species. Other impurities in samples of this seed are sheep's fescue, hair grass (Fig. 9), ox-eye daisy and various weeds common on poor soil.

Tall oat grass is not usually adulterated, but badly cleaned samples are apt to contain a good deal of chess grass (*Bromus secalinus* and *racemosus*, Fig. 15). Samples imported from Europe are apt to contain seeds of yellow oat grass (Fig. 16), which is, however, a good grass, and of poison darnel (*Lolium temulentum*), which is a dangerous weed. Fig. 17 shows the true tall meadow oat grass. It will be observed that the awn starts from near the base of the husk, whereas in case of yellow oat grass the awn starts from above the middle. The tall oat grass seeds are longer and more slender than those of yellow oat grass seeds.

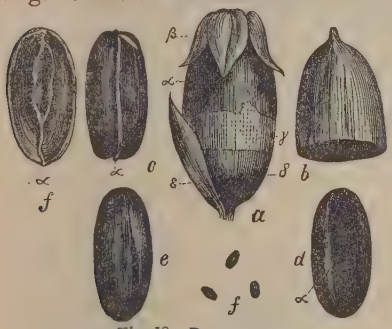

Fig. 18. PLANTAIN.
a. fruit, with attached corolla; B. the four corolla petals; *c*. twin seeds; *d*. the inner surface of seeds; *e*. back of seed; *f*. seed, natural size.

Timothy grass seed is not usually adulterated with other seeds, but sand and crushed quartz rock have been detected in samples. As a rule, timothy is the cleanest seed sold in the market. "Uncleaned seed," however, is likely to include seeds of weeds common on moist soils—plantain (Fig. 18), dock, buttercup, etc., and also seeds of Kentucky blue grass. Pigeon grass (*Setaria glauca* and *viridis*, Figs. 21 and 22) are also present in uncleaned samples of timothy.

Fiorin seed is nearly all imported from Europe, where this grass is found chiefly in parks and woodland pastures. Commercial seed is obtained principally from the latter, and is apt to be mixed with seeds of weeds found in such places. Dog's tooth bent (*Agrostis canina*), tufted hair grass (*Aira cæspitosa*) and timothy (*Phleum pratense*) are the most common impurities. When fiorin grass is allowed to become over-ripe before harvesting, the seed shatters out very readily, and in commercial samples a large proportion of the glumes or seed husks contain no seed. Sand and dirt are always present in uncleaned samples, which is difficult to remove, because, as the seed is so light, in running through a fanning-mill a large proportion is blown away. The same holds good of *Poa trivialis* and *P. serotina*.

The Clover Family.

The clovers are the most frequently adulterated, and generally the foulest samples found in the markets. Crushed quartz rock, either plain or colored, to resemble true seed, has been frequently employed where dealers do not fear detection. Old, discolored and worth-

less seeds are often dyed and mixed with fresh seed. These "doctored" seeds can be detected by pouring some of the seed upon a clean white cloth, slightly moistened, and rubbing the seeds thereon. The cloth will remove the artificial coloring and show it. Quartz grains can be readily detected by examining the seeds with a magnifying-glass. "Uncleaned" samples often contain one-fifth of their weight in weed seeds, the most common of which are plantain (*Plantago lanceolata*, Fig. 18), sheep's sorrell (*Rumex acetosella*, Fig. 19), chick weed (*Cerastium triviale*, Fig. 20), pigeon grass (*Setaria glauca* and *S. viridis*, Figs. 21 and 22), ox-eye daisy, dog fennel, and buttercup (Fig. 8). Seeds of a parasitic plant commonly known as dodder, "devil's-gut" and "gold thread," are usually present in samples of clover and lucerne imported from Europe. These plants, botanically called *Cuscuta epilinum* and *Cuscuta trifolii*, are shown at Fig. 23 and Fig. 24. Samples which contain even a trace of seeds of this parasite should be rejected, whatever be their price. A full account of this weed was given in Bulletin 70 of the North Carolina Experiment Station.

Fig. 19. SHEEP'S SORRELL. *a*. seed in hull; *b*. naked seed; *c*. natural size.

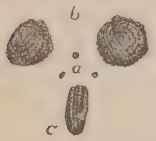

Fig. 20. CHICK WEED. *a*. natural size; *b*. magnified; *c*. same in profile.

Fig. 21. GREEN PIGEON GRASS. *a*. *b*. back and front views, enlarged; *c*. natural size.

Fig. 22. YELLOW PIGEON GRASS. *a*. magnified to show marking; *b*. natural size.

Alsike clover (Fig. 25) seed is largely imported from Europe, and is apt to contain dodder seed (Fig. 25—on the ground), which, being of nearly the same size as the clover seed, is very difficult to get rid of. Uncleaned samples are more or less infested with seeds of buttercup (Fig. 8), plantain (Fig. 18), sheep's sorrell (Fig. 19), and chick weed (Fig. 20)

Crimson clover seed is generally much cleaner than other clovers, and the samples are not frequently adulterated. The most common impurities are plantain (Fig. 18), ox-eye daisy, and sheep's sorrell (Fig. 19).

Fig. 23. FLAX DODDER. *a*. natural size; *b*. magnified; *c*. double seeds.

Japan clover is usually sold in the husk, and is not adulterated. Neither does it contain as impurities other kinds of seed, for Japan clover permits no other plant to grow among it. Samples are, however, often very dirty with sticks, stones and trash. In dry seasons the seeds do not fill well. Good seed should weigh 24 pounds per bushel.

Lucerne seed is largely imported from Europe, and is apt to contain dodder (Figs. 23 and 24), plantain (Fig. 18), common pimpernel (*Pimpinella saxifraga*, Fig. 26), and seeds of composite weeds. American-grown seed samples are apt to contain seeds

of hog weed (*Amarantus spinosus*), dog fennel, and pigeon grass (Figs. 21 and 22). European lucerne seed is generally better than American-grown seed. The best comes from Provence, in France.

Red clover seed is not now imported from Europe. The most com-

Fig. 24. CLOVER DODDER. *r*. section of seed; *c*. endosperm; *v*. vegetation point.

Fig. 25. ALSIKE CLOVER. *a*. natural size; *b*. side view, showing rootlet; *c*. profile view.

Fig. 26. COMMON PIMPERNEL. *b*. double fruit; *c*. *d*. single fruit, back and front view, enlarged.

mon adulterants are quartz grains, which can be detected by using a magnifying-glass. Uncleaned red clover seed is probably the foulest seed on the market. The most common impurities are plan-

Fig. 27. RAG WEED, HULLED SEED, WITH PAPPUS. *a*. natural size.

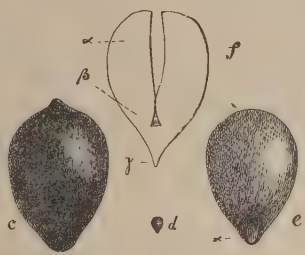

Fig. 28. RAG WEED. *c*. without pappus and cut open; *d*. natural size; *d*. *e*. naked seed; *f*. section of seed, showing cotyledons.

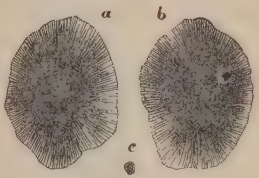

Fig. 29. RANSTED WEED. *a*. *b*. front and profile views; *c*. natural size.

tain (Fig. 18), sheep's sorrell (Fig. 19), pigeon grass (Figs. 21 and 22), rag weed (*Ambrosia artemisæfolia*, Figs. 27 and 28), ransted weed (*Linaria vulgaris*, Fig. 29), corn cockle (*Agrostemma githago*, Fig. 30),

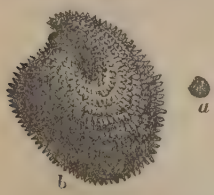

Fig. 30. CORN COCKLE. *a*. natural size; *b*. magnified.

Fig. 31. WHITE CLOVER. *a*. natural size; *b*. side views, showing rootlet; *c*. profile.

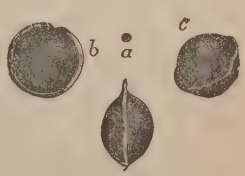

Fig. 32. SPURRY. *a*. natural size; *b*. *c*. *d*. different views, magnified.

dog fennel, ox-eye daisy, and wild carrot. Dodder (Fig. 24) is also apt to be present in samples of red clover, though not so often as with lucerne. The least trace of dodder should condemn the sample.

White clover seed (Fig. 31) is, to some extent, imported from Europe, and is sometimes adulterated with old and dead seed, colored and

"doctored" with sulphur to resemble fresh seed. Quartz grains, either plain or colored, are used for the same purpose. The most common impurities in badly cleaned samples are plantain (Fig. 18),

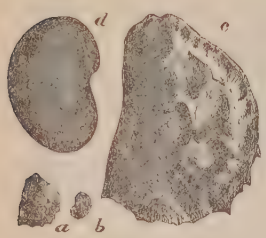

Fig. 33 SANFOIN.
a. c. hulled seed; *b. d.* naked seed; *a.* and *b.* natural size.

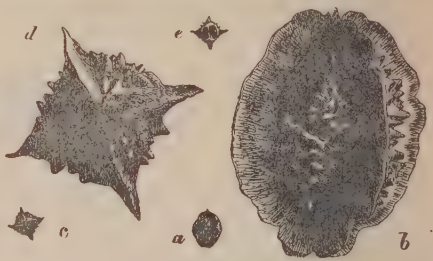

Fig. 34. RED PIMPERNEL.
a. b. c. d. different views of the fruit; *e.* section of fruit, showing two seeds; *a. c. e.* natural size.

sheep's sorrell (Fig. 19), and spurry (*Spergula arvensis*, Fig. 32). Dodder may be present in samples of white clover, but it does not affect this species as much as it does red clover, alsike clover, and lucerne.

Fig. 35. SERRADELLA.
a. b. loments; *c. d.* naked seed; *e.* seed in profile.

Sanfoin seed is all imported from Europe, and almost always contains more or less seeds of the red pimpernel (*Poterium sanguisorba*, Fig. 34).

Serradella seed is nearly all imported, and is apt to be infested by red pimpernel.

3.—LIMITS OF THE POSSIBLE ERROR IN SEED TESTING.

In all kinds of analytical work—chemical as well as physiological—it is customary to allow a margin for possible error, whose limits are defined by the mathematical law of chances. The general theory is ably and exhaustively discussed by Jordan, *Handbuch der Vermessenkunde* (Stuttgart, 1888). The theory has been applied to the error arising from subjective causes in seed testing, by Dr. H. Rodewald, of the Kiel Experiment Station in Germany. A full translation of Dr. Rodewald's paper can be found in Agricultural Science, Vol. 5, Nos. 3 and 4. The original is found in *Versuchs Stationen*, 1889. The following is a synopsis of Dr. Rodewald's paper:

The limits of error in the seed testing process depend upon three different factors, viz.: 1. The apparatus and method used. 2. The execution of the process. 3. Pure accident. The last factor is the most important. The apparatus and method must be assumed to be the best attainable at the time, and can be improved as experience allows. Where a uniform apparatus and method are used by all public and private stations, the errors arising from this cause neutralize each other, and the relative or comparative value of the work

is not affected. The execution of the process must be assumed to be in the hands of competent experts, or the value of the work is *nil.* The error of pure accident arises from selecting particular seeds in separating the sample for testing. As a general rule, one cannot tell by mere visual inspection whether a seed is viable or not, and the viable and non-viable seeds in non-sophisticated samples are mixed together without order or arrangement. It depends, therefore, upon pure accident whether the ratio of the viable to the non-viable in the sample separated for testing is the same as that in the entire sample. Error of this kind falls under the law of chances, and is the only error of which mathematical theory can take cognizance.

If by any competent method we undertake to separate the viable from the non-viable seeds in a sample, the viability of each seed taken alone will be either 1 or 0. It depends upon the quality of the sample how often 1 or 0 appears. From a series of such observations we take the arithmetical mean as the average viability of the sample in terms of per cent. The greater the number of terms in the series, the closer will the arithmetical mean approximate to the true viability of the sample. It follows from this proposition that we can form a table in which, for each per cent. of viability from 0 to 100, the theoretical error is contained, and the agreement between the theoretical and the true error will be greater as we take for the test 100, 200, 300, or more seeds. The mathematical theory gives the following algebraic formula for calculating the mean error (m):

$m=\sqrt{\frac{v\,v}{n-1}}$ (Formula 1), in which n is the number of observations, or, in this case, the number of seeds used; $v\,v$ is the sum of the square of the variation from the arithmetical mean.

Example: Suppose we have a sample of 5 seeds, whereof 1 fails and 4 germinate, we may form the following table:

Seed.	Viability.	Variation from arithmetical means.	Square of the variation.
1st seed	1	$+\frac{1}{5}$	$\frac{1}{25}$
2d "	1	$+\frac{1}{5}$	$\frac{1}{25}$
3d "	1	$+\frac{1}{5}$	$\frac{1}{25}$
4th "	1	$+\frac{1}{5}$	$\frac{1}{25}$
5th "	0	$-\frac{4}{5}$	$\frac{16}{25}$
			$v\,v=\frac{20}{25}$

Therefore, $m=\sqrt{\frac{\frac{20}{25}}{5-1}}=0.447$.

Having found the average error of each single observation, we may then ask, How large is the mean error of the arithmetical mean of n observations? Representing this error by M, we get the following equation:

$$M=\frac{m}{\sqrt{n}}\text{ (Formula 2.)}$$

This equation is very important, since it shows that the mean error of the arithmetical meandiminishes as the number of observations in the series increases.

Where we use only five seeds in a germinating test, and from the result—4+0 good seeds—the arithmetical mean of these five tests be taken as the viability of the sample, the possible error due to chance amounts to 13.48 per cent. Once in four or five trials this error is liable to be doubled. Once in twenty-two trials the error may be trebled, or 40.44 per cent., and so on. In practical work such uncertainty is wholly impermissible. But, as Formula 2 shows, the possible error decreases as the square root of the number of observations increases. By increasing, therefore, the number of seeds taken for the test, the possible error may be made as small as we wish.

Theory shows that the probable error becomes inconsiderably small only when we use over 400 seeds. On the other hand, we must remember that subjective errors—those due, for instance, to miscounting—increase as the number of seeds increase, and therefore it is not advisable to exceed the number of 400. Nobbe, in his *Handbuch der Samenkunde* (Berlin, 1876, p. 508), says: "It is important that a minimum of 200 seeds, an optimum of 400, or a maximum of 600 seeds, should be used for each test if we wish to ascertain the true quality of a sample." It speaks well for the acumen of this investigator that he, by the empirical method, should have discovered the exact number which the theory of probability shows to be the best.

Using always, then, 400 seed (200+200) for the test, we may calculate the possible error due to accident—an error which is unavoidable, even in the most careful work. For example, when the apparent viability lies between 90 and 95 per cent., the possible error lies between 1.02 and 0.74 per cent. But when the apparent viability is 50 per cent., the error is 1.69 per cent., in round numbers 1.7 per cent. The error will also be doubled once in 3.4 to 4.6 cases; will reach 5.1 per cent. once in 22 cases; 6.8 per cent. once in 142 cases; 8.5 per cent. once in 1,341 cases, and so on.

If the apparent viability of a sample is 50 per cent., one may calculate that in 22 tests the allowable latitude of 5 per cent. will be once exceeded, but where the viability is 95 per cent. a variation of 4.4 per cent. will occur only once in 19,230 cases.

A very extensive series of practical germinating tests—over one thousand—made at the Kiel Station, has shown that the error as found by the empirical method follows the theoretical law. The agreement is particularly close in regard to clover and similar seed and awnless grasses, while it is much less close with awned seeds, as the latter do not mix so readily or thoroughly. Errors larger than the theory indicates, are usually to be ascribed to defects in the apparatus or execution of the tests.

Below is given the latitudes for different degrees of guaranteed viability, in the case wherein the exactitude is such that the latitude is theoretically liable to be exceeded only once in 22 trials:

Apparent viability. Per cent.	Latitude allowable for error.	Variation allowable between the two parallel tests. Per cent.
100	0	0
95	2.22	4.62
90	3.06	6.49
80	4.08	7.62
70	4.65	9.78
60	4.98	10.38
50	5.07	10.65

These latitudes refer to guaranteed and found viability of 400 seed sample; the variation refers to two parallel tests of 200 seeds each. If we multiply the variation by two, we get the number of sprouted seeds by which one of the duplicated tests may exceed the other, and yet remain a trustworthy test. If we divide the 400 seeds into four equal parts and test each 100 seeds separately, the variation allowable between the different tests may be greater, according to the following table:

Apparent viability. Per cent.	Allowable variation between duplicated tests. Per cent.
100	0
95	6.57
90	9.04
80	13.06
70	13.82
60	14.77
50	15.08

If the variation between any two parallel tests is greater than given above, the tests are unreliable, but within the limits given the variation does not vitiate the test.

The foregoing calculations show that Nobbe argued correctly when he said that a latitude of 5 per cent. between guaranteed and found viability was the maximum allowable for a viability of 50 per cent., and that between parallel trials of 200 seeds each a difference of more than 10 per cent. vitiates the test. Theory gives the allowable difference as 10.65 per cent. When the viability falls below 50 per cent., the permissible latitude falls in the same ratio as from 50 to 100 per cent., so that for a viability of 40 per cent. the latitude is the same as for one of 60, and so on down to 0 per cent., which has the same latitude as 100 per cent.

In practice it will not be necessary to employ all the latitudes herein discussed. Probably the most satisfactory way is to use, for all samples having a viability of 90 per cent. and over, a latitude of 3 per cent.; for all samples below 90 per cent. use the 5 per cent. latitude advised by Nobbe.

4.—METHODS AND APPARATUS USED IN SEED TESTING.

A. Germinating Apparatus.

In testing seeds the most important piece of apparatus is the germinating pan. Of this there are several forms in use, the best known of which are here described, beginning with the oldest form.

1. THE NOBBE GERMINATING PAN.

This consists of a square of porous baked clay, about 8 x 8 inches and $1\frac{1}{2}$ inches thick. The bottom and the sides for about $\frac{1}{2}$ inch above the base are glazed on outside. On the surface of this square is sunk a ring or fosse 1 inch deep and 1 inch wide. This fosse surrounds a circular space of about $4\frac{3}{4}$ inches in diameter, which has a concave surface, forming a shallow dish about 4 inches in diameter.

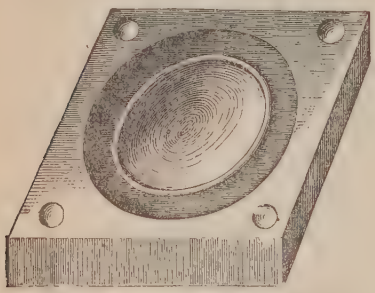

Fig. 36. NOBBE SEED GERMINATING PAN.

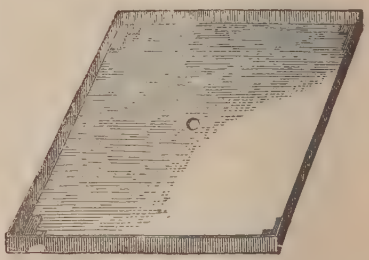

Fig. 37. COVER FOR NOBBE PAN.

Over the whole is fitted a cover having a central orifice of about $\frac{1}{4}$ inch diameter for ventilation. The seeds are placed in the central dish, water is then poured into the fosse, the cover is placed on, and the whole pan set away in a suitably heated and darkened chamber.

The Nobbe pan gives good satisfaction when one has plenty of room and facilities for supplying different temperatures, but for general use it is too cumbrous, and, with ordinary facilities, is inconvenient for germinating seeds requiring different temperatures. This pan is made in Germany, and is sold by Paul Parey, of Berlin. The cost laid down in New York, duty free, is about $12 per dozen.

2. THE ZURICH PAN.

This consists essentially of a round porous plaster disc, about 2 inches in thickness, having a shallow depression on the surface, a little larger than the central dish in the Nobbe pan. This pan, with others, when in use, are sunk to nearly the rim in moist sand contained in a metallic outer pan or case, which has a cover. The sand is kept moist by sprinkling it with water, and is heated by gas-jets underneath, the flow of the gas being regulated by means of a thermostat. This is a great improvement upon the Nobbe pan, as regards compactness. It is much less cumbrous, and where a great deal of seed testing is done, involving the simultaneous testing of many samples of the same species, this apparatus has decided merits, but for miscellaneous work, requiring different temperatures, it is not entirely satisfactory. Its cost is moderate, as the outside pan can be made by any metal smith, while the interior dishes ought not to cost above ten cents each, or may be made of plaster paris by any one.

3. THE VIENNA GERMINATING APPARATUS.

Fig. 38 shows a form of automatic germinating apparatus used at the Austrian Seed Control Station at Vienna. In this apparatus the seeds are placed between double folds of moist filter-paper, which

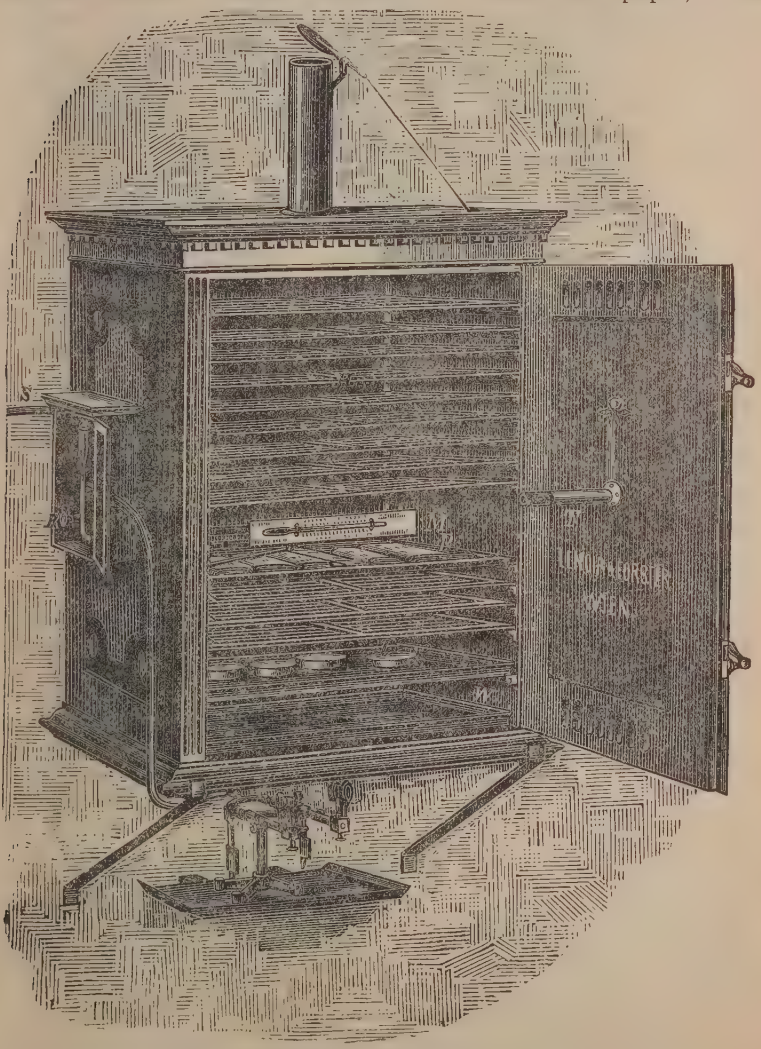

Fig. 38. VIENNA SEED GERMINATING APPARATUS.

opens as does a book. These papers may be laid upon supports of glass strips in a light-tight, zinc-lined chamber, heated from below by gas-jets, whose energy is controlled by means of a thermostat.

The door of the chamber has an automatic ventilator worked by the thermostat. A zinc pan at the bottom of the chamber holds water, evaporation of which furnishes sufficient moisture to keep the filter-paper damp. Another zinc pan above the water-pan contains sterilized sand for "earth tests." In this the Zurich or Kiel dishes may be placed. This form of apparatus has the merit of great compact-

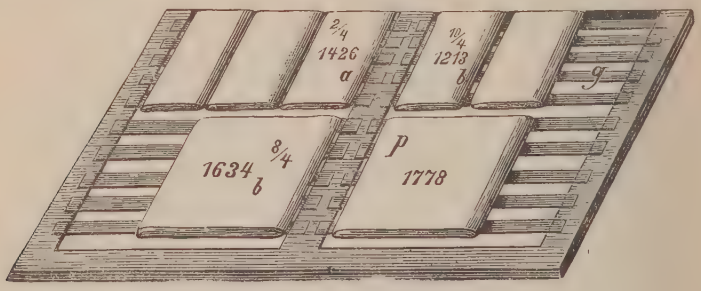

Fig. 39. Tray used in Vienna Apparatus.

ness, simplicity and ease of access and control. Its inventor, Dr. Weinzierl, claims to have obtained better results with this than with either the Nobbe or Zurich apparatus. So far as known, this form of germinating apparatus has not been introduced into this country. Its cost (size 89 x 65 x 38 centimeters) is about $30, without accessories. The accessories cost about $20 additional, all estimated at duty-free rates.

4. THE KIEL PAN.

The essential part of this apparatus is a small square shallow porous dish, about 2½ inches square and ¼ inch deep. Each of these dishes will conveniently hold 200 clover seeds or 100 grass seeds. These dishes are sunken to the rim in a layer of moist sand which has been carefully sterilized, and the whole is contained in a metallic dish of convenient size. From 25 to 100 dishes are usually contained in one outside pan. The heat is supplied by gas-jets below, and regulated by means of a thermostat. This is more compact than the Zurich pan.

5. THE GENEVA PAN.

This apparatus, originated by the Geneva (New York) Agricultural Experiment Station, consists of a copper reservoir about 9 x 14 inches and 3½ inches deep. This has a shoulder or shelf along the two longer sides, about ½ inch from top. Resting on this shelf, stiff brass wires run crosswise of the reservoir and support pockets of canton flannel, fuzzy side out, into which the seeds are placed. Water is then poured into the reservoir, sufficient just to touch the bottom of the pockets, and a cover of metal or glass slides into a groove in the top of the reservoir, thus completely shutting out the air.

The Geneva apparatus has the merit of extreme compactness, as within the space indicated a large number of samples may be tested at one time. The tendency of seeds, like all bodies possessing weight, is to seek the lowest level. In the pockets of this apparatus smaller seeds will pile upon each other, shutting out the oxygen necessary for starting the germ, and giving special facilities for development of molds. The seeds, too, are very apt to become too dry, or are drowned by a surplus of moisture. Finally, it is not very easy to see and remove the sprouted seeds, and the white cloth furnishes an undesirable surrounding for the seeds, since it reflects too much light. This apparatus is not patented, and may be made by a coppersmith; costs about $3.50.

6. THE NORTH CAROLINA PAN.

This apparatus consists of a zinc pan resembling an ordinary bread baking pan, 7½ x 15½ inches, and 2 inches deep. Within this are four zinc trays on legs 1¾ inches high. These trays have a raised rim ¼ inch high all around and across the middle, dividing each tray into two compartments about 3½ inches square. The bottoms of the trays are perforated with holes, varying for different pans from ¼ to ½ inch in diameter. A ventilated cover goes over the pan, shutting out all light except that entering through small ventilating pinholes, of which there are two dozen, three at each corner and twelve under the handle on middle of pan. The interior of the pan and all the trays are blackened with asphalt paint to absorb light. Squares

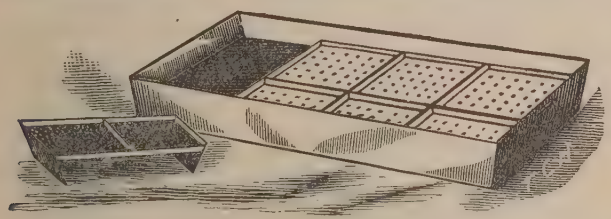

Fig. 40. North Carolina Seed Germinating Pan.

of thick black woollen cloth, sterilized by boiling for five minutes just before using, are laid upon the perforated trays and moistened with distilled water. Upon these are placed the seeds to be germinated. Water to the depth of about one inch is then poured into the zinc pan, the cover placed on, and the pan laid away in a properly heated chamber. This chamber at the North Carolina Experiment Station consists of a large case, with glass door, 4 feet wide, 1½ feet deep and 9 feet high. Shelves upon which to support the pans are made of ¼-inch iron rods. Heat is supplied by an alcohol burner in the bottom of the chamber. Thermometers hung to the top, bottom and center shelves show the temperature. The temperature is regulated by two pair of ventilators at top and bottom of case. After a little preliminary practice with the burner and ventilators the tem-

perature can be regulated to a nicety in our mild and constant climate, but where the temperature of the air and room is liable to sudden and considerable fluctuations, a thermostat would be necessary to insure a constant temperature.

This apparatus, after long use at the North Carolina Experiment Station, has given better average results than either the Nobbe or Geneva apparatus, and better than folded filter-paper laid on moist sand. The cost of the pan is about $2.50. The case, heater, thermostat, etc., are extra.

7. OTHER FORMS OF GERMINATING APPARATUS.

The Botanist of the Royal Agricultural Society of England, for germinating seeds, stands two porous clay bricks on end in a pan of water, and upon these supports a third brick, upon which the seeds are placed. The whole is kept in a dark suitably heated chamber.

A convenient slab of porous baked clay, 12 to 18 inches wide by 2 inches thick, with shallow depressions of about $\frac{1}{2}$ inch depth and 4 to 6 inches diameter on surface, placed in a covered trough holding about one inch of water, has been used by some botanists in sprouting seeds. The chief objection to this is the impossibility of varying temperature and humidity to suit different species of seeds.

Copper, zinc or earthenware pans or plates of any convenient size, containing a layer of sterilized moist sand, upon which are laid pieces of blotting-paper or flannel, between the folds of which the seeds are placed, have been considerably used for seed testing.

Washed and ignited sand, held in any suitable vessels, such as flower-pots or "flats," may be used directly for sprouting seeds. With large seeds this gives satisfactory results, but small seeds are apt to be lost in the sand, and numerical accuracy cannot be assured.

B. Seed Separators.

1. SEPARATION BY SIEVES.

Sieves of different size of mesh are used to separate straw, dirt, etc., from seeds. The separator used at the North Carolina Experiment Station consists of a series of shallow tin cylinders about 4 inches in diameter and 2 inches deep, each piece of which has a perforated bottom of different sized and graduated holes. The pieces slip over the next piece below and under the next above, like links of a stovepipe. Any number of the separable pieces may be used in such a combination. The top piece has a cover, and the bottom a tight base. The size of hole is graduated from the top to the bottom of the combination. The seeds are put in at the top and the cover put on, and the whole agitated for five minutes. This separates the sample into different sized heaps of graded fineness. The bulk of each kind of seed, or of matters of similar size contained in the sample, is found together in one of the compartments. For ordinary small

seed samples, however, it is customary, and takes less time, to spread the sample on a sheet of clean white paper and remove the impurities by hand, using a magnifying glass or simple microscope, when necessary. Some European stations use elaborate separators, such as are illustrated at Fig. 41 and Fig. 42. It is a special agitator for separating dodder from clover seed. Its construction is the same as the hand separator above described, but each dish shown in the cut has but one sieve. The bottom of the upper section is removable, so that sieves of different sized mesh may be used when this apparatus is used as a general separator.

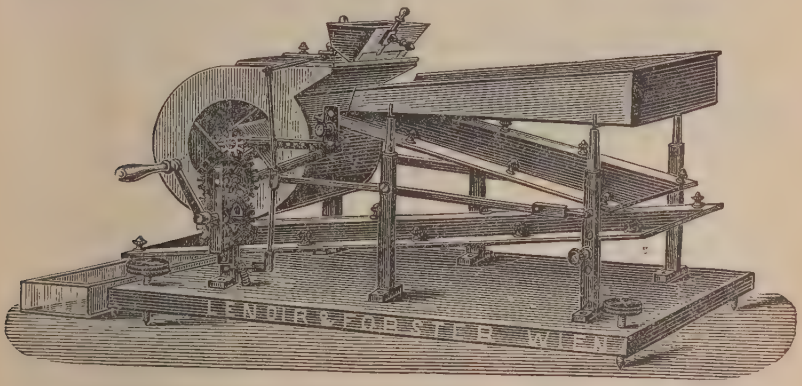

Fig. 41. Precision Separator, for Determining the Amount of Straw and Chaff in Meal and Seed Samples.

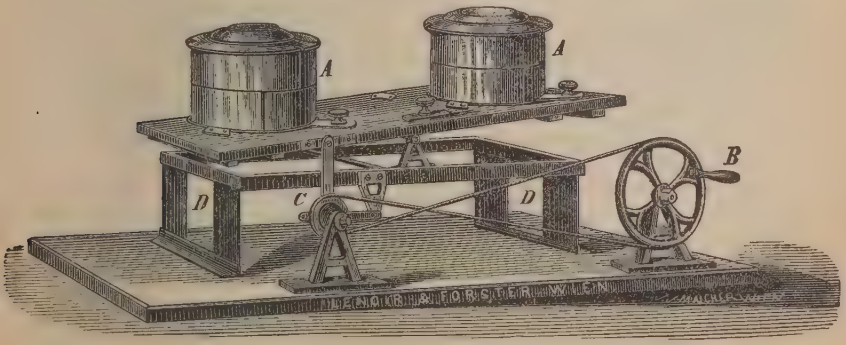

Fig. 42. Sieve Separator, with three Sieves.

2. THE AIR SEPARATOR, OR SPREUFUGE.

Fig. 43 shows a useful piece of apparatus for removing straw, chaff, etc., from seeds and meal. It is called the "spreufuge." In using the spreufuge, the sample to be cleaned is placed in the inner glass jar, which must not be more than one-half filled; the cover is then put on and the joint covered with a wide rubber band. The bent

glass tube is then placed down to the bottom of the jar and air forced through from the hand-bulb. This brings all chaff, straw, and germless seeds to the surface, where they can be blown out into the larger vessel.

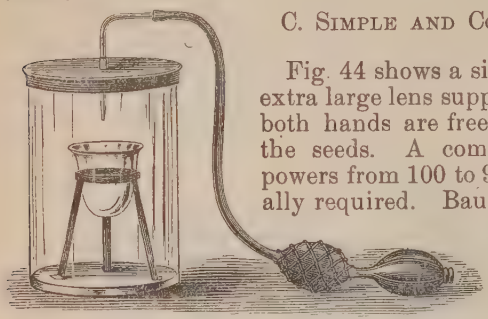

Fig. 43. Air Separator, or "Spreufuge."

C. Simple and Compound Microscopes.

Fig. 44 shows a simple microscope, with an extra large lens supported to the stand, so that both hands are free for use in manipulating the seeds. A compound microscope, with powers from 100 to 900 diameters, is occasionally required. Bausch & Lomb's (Rochester, N. Y.) European models are good and cheap.

D. Volume Weight Apparatus.

This consists of a standard measure (litre) attached to a druggist's scales, for weigning the measured contents.

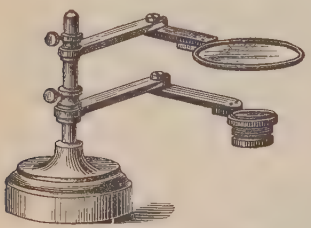

Fig. 44. Simple Microscope.

E. Sampling Apparatus.

For taking samples from grain-sacks and large bulks, a hollow brass tube about $\frac{3}{8}$ inch in diameter, closed and sharpened at one end, is used. This has within it a smaller tube, which turns easy, but cannot be pulled out. At the upper end is a handle. The two tubes have opposite slits at different depths of tubes. When the apparatus is thrust into a heap and the inner tube turned till the slits come opposite, it at once fills with the material through the slits at different depths, giving a composite sample. Several such samples are taken from large bulks, and from these, after mixing, a smaller sample is taken for examination. There is a similar but smaller sampler for use with clover and small seeds.

F. Analytical Balance.

For weighing seeds and their impurities, a good analytical balance must be used. It should weigh as high as 300 grams, and be sensitive to one milligram.

G. Miscellaneous Apparatus.

A sharp-pointed spring forceps for picking up seeds, a thin-bladed knife for counting seeds, a few dissecting needles, a razor, a large reading-glass, some white printing-paper, and filter-paper are necessary. A florist's bulb atomizer for moistening seeds, and an ordinary cylindrical syringe for removing water from the pans are about all the additional apparatus required.

H. Record Books and Blanks.

1. North Carolina station records and blanks.

At the North Carolina Experiment Station the following blank forms are used in seed work:

A. Sampling Blank. [Size, 7 x 8½ inches.]

This is sent to the person desiring to have a test of seeds made.

[*a*. Face side.]

N. C. Experiment Station.

FORM FOR SENDING SEED SAMPLES.

This form must be filled up completely, or sample may be rejected.

(To be left blank.)

Station No. B.---- ----189--

Received---- Dr. H. B. Battle, Director Experiment Station,

RALEIGH, N. C.:

Sir: I send you today, marked ---- contained in a----, a fair sample of seed, drawn according to directions on opposite of this sheet.

Kind of seed ----
Sold by ----
At city or town of ----
Grown by ----
in---- County, State of----
(Sender of sample must give following particulars:)
1. Supposed name of the plant which produced the seeds ----
----
2. The year in which the seed were said to be matured ----
3. The price paid for the seed, or for which they were offered for sale----
4. Other particulars----

Name of sender ----
Post-office ----
County ----
State ----

[*b*. Reverse side.]

N. C. Experiment Station.

DIRECTIONS FOR TAKING SAMPLES OF SEED.

If the seeds are in small packages, pour out the contents of the package on a sheet of clean paper, mix thoroughly and take a sample of at least one ounce and place it carefully in a clean envelope. If seeds are in bulk or large packages, take a handful each from different depths and parts of the packages, mix these on a sheet of paper, and from this take the sample to be sent to the Station.

N. B.—The Station makes analyses for the citizens of North Carolina without charge, provided—

1. That the results are of some use to the PUBLIC and the Station is free to publish them.

2. That the samples are taken according to our directions for sampling, and are fully described.

3. And provided further, that the person sending the seeds desires the information to aid him in selecting seed for his own use. The Station cannot, as a rule, undertake to do such work for merchants or those who have seeds to sell.

Samples, when accepted, will be entered upon our register in the order of their coming, and tested in turn.

The results of each examination or analysis will be promptly communicated to the person sending the sample. Results of general interest will be sent simultaneously to the State newspapers or published in the Station Bulletin or Report.

Samples should contain at least 400 seeds and weigh at least one ounce, and should represent a fair average of the whole. Such samples may be sent by mail in pasteboard boxes or common envelopes. The postage is one cent for each two ounces. Postage must be prepaid in all cases.

It will usually be one week in the case of clover seed, and two weeks in the case of grass seed, before a report upon their vitality can be made.

Write your name and address, preceded by the word "from," upon all packages, and put some mark, word or number upon them by which to identify them. THIS IS VERY IMPORTANT. Address all packages to

N. C. AGRICULTURAL EXPERIMENT STATION,
RALEIGH, N. C.

B. Seed Record and Register. [Size of page, 7 x 8½ inches.]

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION.

SEED RECORD.

Received .....

Station No. ..... Reported .....

Sent by ..... From .....

Marks ..... Quantity .....

Scientific name .....

Common name .....

No. of seeds in one gram ..... No. of seeds in one ounce .....

Purity, per cent., ...

Nature and percentage of impurities .....

Viability, per cent., ... Real worth, per cent. .....

(Original.)	GERMINATION TEST.	(Duplicate.)
.....	Experiment begun	.....
.....	Number of seeds used	.....
.....	Date of first germ	.....
.....	Date of last germ	.....
.....	One-half of sample germinated in days	.....
.....	Total germinated seeds	.....
.....	Number of hard seeds remaining	.....
.....	Experiment concluded	.....
.....	Range of thermometer	.....

..... } Remarks. { .....

..... } { .....

..... } { .....

....., Botanist.

NOTE.—The most convenient size of seed record and register is a page 7 x 8 inches, with forms on both sides. It should be strongly bound in book, with water-proof corners and back. The paper should be of good quality and not blister when wet.

C. Seed Report Blank. [Size, $7\frac{3}{4}$ x $10\frac{1}{2}$ inches.]

Division of Botany and Entomology.
GERALD MCCARTHY, B. Sc.,
Botanist and Entomologist.

THE NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION,

H. B. BATTLE, Ph. D., Director.

Botanical Analysis
No. B .....

RALEIGH, ..., 18..

SIR: The sample of seed sent to the station for examination in a....., marked....., was received .....

The Botanist of the Station reports the bulk of the sample to be seeds of .....(Botanical name)
.....(Common name)

The sample contains ..... per cent. of true seed of the plant named, and ..... per cent. of impurities.

The impurities consist of { useful seeds, ...per cent.
noxious seeds, ...per cent.
inert matter, ...per cent.

The sample is calculated to contain ..... seeds to the ounce.

One-half of the seed germinated in ..... days.

There are in every 100 pure seed ..... seed capable of germinating.

There are in 100 parts by weight of the sample ..... parts of pure viable seed. This determination measures the real or cultural value of the seed.

The germinating test indicates that the seeds possess ..... vitality. Choice merchantable seed of this species should have—purity, ...per cent.; viability, ... per cent.; making the real worth .... per cent., and should be free from .....

Your obedient servant,

....., Director.

To.....

.....

NOTE.—Seed samples sent for examination and test should be taken according to our directions, and must be fully described. At least 400 seeds, or one ounce by weight, should be sent. Of the larger and heavier sort, two ounces.

2. ZURICH STATION BLANKS.

Dr. F. G. Stebler, Director of the Zurich Seed Control Station, has kindly furnished copies of blanks used in that Station, of which copies translated into English are here subjoined.

A. Seed Mailing Envelope. [Size, open, 4 x $8\frac{1}{2}$ inches.]

SIZE OF SAMPLES.
Grasses, . . . 40 grams.
Clovers, . . . 100 grams.
Sanfoin, Lupine, Cereals, etc., . . . 250 grams.

SAMPLE .... OF NO VALUE.

THE FEDERAL CONTROL OFFICE FOR SEEDS,

ZURICH.

Sender's name: .....

OBERSTRASSE,

Switzerland.

The above described envelope is made of tough manilla paper, and has a round-headed brass fastener attached at open end. These envelopes are supplied by the Station to its patrons.

B. Preliminary Report Blank. [Size, 5½ x 8½ inches.]

PRELIMINARY OPINION AND PURITY.

No.----- Entry date----- } 18--
Opinion date----- }

Label:-----

Right name: -----

Guarantee:-----per cent. purity, ------ per cent capability of germination.

Quality, price, etc.: -----

Seal:----- Witnesses: -----

The sample contains:

-----per cent. pure seeds (Purity)

-----per cent. foreign seeds, as:-----

------ per cent. earth, sand, small stones, chaff, broken bits, tares.

100.0 per cent.

The sample weighing-----Grams contains-----reckoned per Kilo-----seeds-----

GENERAL REMARKS.

Purity: -----

Quality of pure seeds: -----

Supposed capability in germination: -----

Summary remarks:-----

Opinion of the Control office for the examination of seeds, Zurich (Switzerland).

C. Complete Report Blank (Face). [Size, 11½ x 9 inches.]

CONTROL OFFICE FOR THE EXAMINATION OF SEEDS.

ZURICH, FEDERAL LABORATORY, DATE 18

To .....

in .....

RESULT OF EXAMINATION.

Control-number	Designation of seeds	The sample contains: Foreign substances i. e. Foreign seeds pr. ct.	Earth, sand, chaff, debris, etc. pr. ct.	Pure seeds (Purity) P pr. ct.	Of the pure seeds germinated: In how many days?	Per cent.	Of the seeds remaining "hard" have been accepted as capable of germination pr. ct.	Therefore capability in germination (7+8) G pr. ct.	The goods contain therefore pure seeds capable of germination (real value) $\frac{P \times G}{100}$ pr. ct.	Remarks
1	2	3	4	5	6	7	8	9	10	11

AVERAGE RESULTS OF FORMER EXAMINATIONS.

Designation of seeds	Purity pr. ct.	Capability of germination pr. ct.	Real value pr. ct.	Designation of seeds	Purity pr. ct.	Capability of germination pr. ct.	Real value pr. ct.

The Director of the Control office of seeds:

DR. F. G. STEBLER.

C. *Complete Report Blank* (Reverse side).

REMARKS AND EXPLANATIONS.

1. REAL VALUE. By Real value (column 10) is meant the per cent. of seeds, pure and capable of germination, contained in the goods; it is reckoned by multiplying purity (P) by capability (G) in germination and dividing the product by 100. For example, does purity amount to 90 per cent. and capability in germination of the pure seeds to 80 per cent., the Real value comes to 72 per cent. Such goods are then marked as 72 per cent.—so that 1 pound of 72 per cent. goods has as much Real value as 2 pounds of 36 per cent., or 4 pounds of 18 per cent., or 8 pounds of 9 per cent. goods.

2. PRICE. If the price of 1 pound of 72 per cent. goods comes to 25c., one pound of seeds pure and capable in germination (= 100 per cent.), 25c. × 100: 72, comes to 34.7c. When both the per cent. Real value and price are known, the value of goods is easily found. Those goods are the most profitable in which the pound of pure seeds and capable in germination comes cheapest. You can often discover by a simple reckoning that the goods which are cheapest in gross weight are really the dearest, and *vice versa*.

3. CAPABILITY IN GERMINATION. The given per cent. capability in germination is the average of a trial with at least 2 × 200 seeds. For the experiment in germination it requires 6 days for Hemp, Corn, Vetches; 10 days for Red Clover, Lucerne, Crimson Clover; 12 days for Sanfoin, White Clover, Hybrid Clover, Perennial Rye Grass, Italian Rye Grass, Tall Oat Grass, Meadow Fescue, Timothy, Flax; 20 days for the finer grass seeds, and Beet; 30 days for Fir, Pine, Larch. In the valuation of seeds for capability in germination, of Red Clover, Lucerne, Sanfoin, Crimson Clover, one-half of the hard seeds is used, of the rest a third part. (See column 8.)

4. CHOICE OF A SAMPLE has to be made in such a way that the sample chosen answers to the average quality of the goods. If the seeds are in sacks, samples must be taken from each sack and mixed (from the top, the middle and the bottom of the sack). From this large sample must be taken the average sample to be sent.

5. THE SAMPLES OF PURCHASERS must be taken out of UNOPENED sacks, before witnesses, and be sealed with the seal of a witness. The witnesses are responsible for a right choice of a sample, and have to certify this on a certificate. In important cases two samples of the same goods must be chosen, sealed and sent, of which one is kept for extra examination.

6. THE WEIGHT OF SAMPLES must be at least:

40 grams of grasses (of Timothy 100 grams).
100 grams of clover and such like seeds.
250 grams of the larger seeds, as Sanfoin, Cereals, Vetches, etc.

The result is generally inexact when the samples are small, and the Office refuses every responsibility.

7. GUARANTEE. Whenever possible, it is better to buy the seeds from those seed merchants who are under the Station Control, and to get a guarantee for a certain per cent. of purity and capability in germination. With clover seeds the guarantee must also comprise the freedom from dodder, and with sanfoin the freedom from pimpernel.

8. CONTROL. Each purchaser ought to assure himself at the Control Office, by an after-examination, whether the goods answer to the guarantee or not, for it is often the case that the goods themselves do not agree with the guarantee in the least. The seeds sent in generally undergo a preliminary examination within twenty-four hours after their arrival, the result of which can, if desired, be sent by telegraph. During the experiment in germination the sender is kept informed from time to time, by means of a postal card, of the progress. At the end of the experiment in germination (see above "Capability in germination") the complete report is given.

9. COMPENSATION. When the Control gives a result in which the Real value is more than 5 per cent below the guarantee, each Control firm is bound by contract to make good the loss or to take back the goods, should the purchaser desire it. Suppose 96 per cent. Purity and 80 per cent. Capability in germination, = 76.8 per cent. Real value are guaranteed, but the Control report gave only 90 per cent. Purity and 60 per cent. Capability in germination, = 54 per cent. Real value. 17.8

per cent. are to be made good, the remaining 5 per cent. being allowed as margin for the possible error of analysis. If the price of the seeds as guaranteed amounts to 7 cents per pound, 1 per cent. of pure seed capable of germinating would cost 7: 76.8 = .09 cents. As there are 17.8 per cent. to be made good, the compensation per pound amounts to 17.8 × .09 cents. For 100 pounds this is $1.60.

Such a method for calculating the indemnity was agreed upon by the Association of German Seed Testing Stations at Hamburg, December 19, 1876. The agreement reads as follows: "Indemnity = purchase price multiplied by the decreased value found, less 5 per cent., divided by the per cent. of Real value guaranteed. Seeds of which the Real value found by analysis falls 5 per cent. or less below the guarantee are to be considered as good as the guarantee."

D. Private Contract Blank. [Size of page, 8½ x 11 inches.]

PRIVATE CONTRACT.

(Not Control Contract.)

Between .....

and the Swiss Control Office for the examination of Seeds, in Zurich, the following contract has to-day been agreed upon:

The firm .....

has the right to have, every year, commencing from the 1st of July, 18...., till ....., 18...., ... samples fully examined (No. 7, §15 of the Regulations) by the Swiss Control Office for the examination of Seeds, and pays for this to the said Control Office a yearly amount of francs, ..., in words, ... francs.

Should the yearly examinations asked for by said firm exceed ..... in number, then every additional full examination must be paid at the rate of ..... francs.

Part examinations, Nos. 1–6, are charged only in proportion, viz.:

No. 1.	Examination	as to	genuineness	$\frac{2}{10}$
" 2.	"	"	" Pimpernel	$\frac{1}{10}$
" 3.	"	"	" the containing of Dodder.	$\frac{1}{10}$
" 4.	"	"	" purity	$\frac{6}{10}$
" 5.	"	"	" the power of germination,	$\frac{4}{10}$
" 6.	"	"	" quality	$\frac{4}{10}$

} of a full examination.

The examinations provided for in § No. 8–16 are reckoned, independent of this agreement, according to the tariff.

The yearly amount for this private contract of ..... francs has to be paid in advance every 1st of July, and the final account must be settled at the end of every fiscal year, viz., on the 30th of June.

This contract is made out in duplicate, and signed by both parties, with right to cancel it at six months notice given by either side.

This private contract does not give to the firm the right to consider itself as a Control firm. (§16 of the Regulations.)

Zurich, ...

For the Swiss Control Office for the examination of Seeds:

.....

Director.

.....

The seed trade firm:

.....

E. Certificate of Guarantee, and Sampling Blank, given by a Control seed house to every purchaser of seeds. [Size of page, $7\frac{1}{2} \times 9$ inches.]

CERTIFICATE OF GUARANTEE, CONVEYING THE RIGHT OF GRATUITOUS ANALYSIS.

To the Federal Station for Testing Seeds, Zurich, Switzerland:

The undersigned controlled seed house has this day sold to Mr. ....., of ....., the following seeds, with the annexed guarantee of quality. The purchaser is entitled, under our contract, to have a sample tested free of charge:

Marks and number of sacks from which sample is made up.	Name, variety and place of growth of seeds.	Price per kilogram.	Guarantee.		
			Purity. pr. ct.	Viability, pr. ct.	Freedom from certain substances.

Place.....

Date .... Control House of.....

CERTIFICATE OF WITNESSES:

[One witness must attach seal with wax.]

.....witness

Place..... [L. S.] .....witness

Date ..... Signature of purchaser.....

APPENDIX.

CIRCULAR. (*See page 356.*)

[SECOND EDITION.]

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION,

RALEIGH, N. C., May 30th, 1889.

DEAR SIR: The North Carolina Experiment Station has been for some time past engaged in testing the purity and vitality of flower, field and garden seeds sold in the market. The Station has found its work much incommoded and the value of the results greatly depreciated by having no trustworthy standard with which to compare the seeds tested.

Most seedsmen now print upon their seed packets a wholesale disclaimer of responsibility for the worth of the seeds contained therein. So long as the field test—subject, as it always must be, to accidents of the weather and the prevailing ignorance of plant physiology upon the part of the planter—was the only test applicable, such a disclaimer might be permissible. But since the establishment in most of the States of Experiment Stations, with competent botanical specialists and improved sprouting apparatus, by means of which any desired temperature and humidity can be maintained, there seems to be no good reason why the quality of merchantable seeds should not be made to approximate to some recognized standard, as is the case with most other articles of merchandise.

The establishment of a generally accepted standard of seed vitality and purity would greatly benefit the Experiment Stations by enabling them to attain greater exactness in their seed analyses, and in reducing to a uniform basis the work of the several Stations. It would also benefit honorable seed growers, who have at present to contend against the unfair competition of unscrupulous persons who take advantage of the lack of any efficient control to victimize the public for their own private benefit.

This Station has tested many samples of store seeds which contained less than 10 per cent. of viable seeds, and others which contained as high as 40 per cent. of impurities, including seeds of many noxious weeds very difficult to eradicate when once given a foothold.

The North Carolina Experiment Station is desirous of collecting data for the establishment of a LABORATORY STANDARD of value for all the more common flower, field and garden seeds. In seeking to establish such a standard, we are not working for the benefit of the citizens of our own State only. It is the policy of the American Agricultural Experiment Stations for each Station to give special attention to some particular line of work of general utility, and publish the results for the benefit of the public at large.

Our standard will be submitted to a meeting of the officers of the Experiment Stations, and, with such modifications as may be thought necessary, will probably be adopted tentatively as a National Standard. This, then, is a matter that concerns you personally as a business man. It is to your interest that the standard adopted shall be one just and satisfactory alike to the seed grower and the seed user. We are anxious that it should be so, and to this end have sought to enlist the good will and active co-operation of the seed growers of the United States.

When all the answers to this circular have been received, they will be collated and a tentative standard adopted according to the tenor of the replies. The result will be published in a Bulletin to be issued from this Station, a copy of which will be mailed to each person replying to the circular.

Respectfully yours,

GERALD McCARTHY, Botanist.

Approved:

H. B. BATTLE, Director.

INDEX.

Agricultural seed, what are high grade? 382.
Air separator, illustrated, 403.
Alsike clover, illustrated, 393.
  impurities of, 392.
Analytical balance for seed testing, 404.
Apparatus and methods used in seed testing, 397.
Appendix, circular letter to seedsmen, 413.
Ash analyses of seeds, 365.

Bean, section of, 361.
Bermuda grass seed, impurities of. 386.
Blue pearl grass seed, illustration of, 386.
Buckwheat, centripetal floration, 374.
Buttercup seed, illustration of, 388.

Cereal seeds, specific weight of, 372.
  temperature which destroys germ, 366.
Cheap seeds, value of, 354.
Chess seed, illustration of, 389.
Chickweed seed, illustration of, 392.
Clover seed, illustrations of, 393.
Clover, crimson, impurities of, 392.
  red, slow germination of, 363.
Cockle, wheat, illustrated, 393.
Crested dog's-tail grass seed, impurities of, 386.

Dodder seed, illustration of, 392, 393.

Embryo, germination stage, 374.
Embryo, harvest stage, 374.
  inert stage, 378.
  stages of growth, 374.
Endosperm, proximate composition of, 364.
English rye grass seed, illustration of, 387.
  impurities of, 389.
Error in seed testing, limits of, 394.
  formulas for deducing, 395.

Fescue, red, impurities of, 387.
  tall, impurities of, 386.
Fowl meadow grass seed, impurities of, 387.
Fraudulent seed, 353.

Garden seeds, tests of, 352.
Germinating pans, 397.
Germinating pans, Geneva, 400.
  Kiel, 400.
  Nobbe's, 398.
  North Carolina, 401.
  various forms of, 402.
  Vienna, 399.
Germinating tests, 396.
  allowable variation, 397.
  limits of error in, 396, 397.
  number of seeds used, 396.
  parallel tests necessary, 397.
Gliadin in seeds, 364.
Guarantee of real worth of seed in England, 355.

Hair grass seed, illustration of, 388.

Indian corn, section of, 361.
Italian rye grass seed, illustration of, 389.
  impurities of, 390.

Japan clover, impurities of, 392.
Johnson grass seed, impurities of, 387.

Kentucky blue grass seed, impurities of, 387.
  tests of, in Illinois, 351.
Kidney vetch, slow germination of, 363.

Laboratory standard, value of, 356.
Leguminin in seeds, 364.
Legumines, specific gravity of, 372.
Lolium temulentum, 391.
Lucerne seed, impurities of, 392.

Margin allowed in seed guarantee, 397.
Meadow fescue seed, illustration of, 387.
Meadow fox-tail seed, illustration of, 388.
  impurities of, 388, 389.
Microscopes required in seed testing, 404.
Mineral constituents of seeds, 365.
Miscellaneous apparatus for testing seeds, 404.
Moisture, role of, in seed germination, 363.
Mucedin in seeds, 364.

Orchard grass seed, illustration of, 388.
  impurities and adulterants of, 389.

Pigeon grass seed, illustrations of, 392.

Pimpernel, common European, illustration of, 393.
red, illustration of, 394.
Plantain seed, illustration of, 391.
Plants, propagation of, 361.

Ragweed seed, illustration of, 393.
Ransted weed seed, illustration of, 393.
Rational mixing of seeds, 354.
Red clover, impurities and adulterants of, 393.
Red-top grass seed, impurities of, 390.
Record blanks, North Carolina, 405–407.
Zurich, 407–412.
Rescue grass seed, illustration of, 388.
Rough-stalked meadow grass seed, adulterants, 390.
Rye, centrifugal floration, 374.

Sampling apparatus, 404.
Sanfoin seed, illustration of, 394.
Seed control in Europe, 357.
Seed germination, action of chemicals upon, 369.
action of light, etc., upon, 368.
at different temperatures, 368.
Seed guarantee, English form, 355.
proposed American form, 360b.
Seed, how developed, 361.
life stages of embryo, 374.
nature of *testa*, 363.
physiology of, 361.
separators, 402.
structure of, 361.
testing in Europe, 357.
Seeds, comparative value of heavy and light weight, 373.
cultural or real value of, 382.
germination of, 362.
longevity of, 378.
number of days required to germinate one-half a sample, 376, 377.
number of hard to be counted viable, 375.
Seeds, number to be used in a germinating test, 396.
power of withstanding heat and cold, 366.
period between harvest and germination stages, 375.
specific gravity of, 371.
standard of quality, how made up, 382, 383.
volume-weight of, 372.
water-absorbing capacity of, 364.
Serradella seed, illustration of, 394.
Sheep's sorrel, illustration of, 392.
Spreufuge, illustration of, 404.
Spurry seed, illustration of, 393.
Sweet vernal grass seed, adulterants of, 390.
Tall oat grass seed, illustration of, 390.
impurities of, 391.
Temperature, action on seed germination, 365.
maximum and minimum optional for germinating seeds, 367–383.
moist and dry, 365.
Timothy grass seed, impurities of, 391.

Various forms of germinating apparatus, 401.
Velvet grass seed, illustration of, 386.
Viability, decrease of, with age, 380.
tests of old seeds, 379, 380.
Volume-weight apparatus, 404.

Water, quantity absorbed by seeds, 364.
Wheat, variation of specific gravity, 372.
White clover seed, adulterants of, 393, 394.
illustration of, 393.
Wild carrot, illustration of, 389.

Yellow oat grass seed, illustrat'n of, 390.

Zurich Seed Control Station, work of, 350.